

APPENDIX Q

Development of the IEUBK Bunker Hill Superfund Site Models and Bioavailability Estimates

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This appendix contains tables and figures illustrating the IEUBK model and the various inputs used in the model. Data presented includes comparisons of geometric mean blood lead levels, geometric standard deviations and predicted percent of children to exceed 10 µg/dl. Other figures in the appendix represent how different bioavailability estimates influence the prediction of blood lead by the IEUBK model.

DEVELOPMENT OF THE IEUBK BUNKER HILL SUPERFUND SITE MODELS AND BIOAVAILABILITY ESTIMATES

- excerpts and additions to the *Final 1999 Five Year Review Report: Bunker Hill Superfund Site* (TerraGraphics 2000a).

Summary of Blood Lead Analyses Performed for the Five Year Review

Both the “Box Model” and Default versions of the Integrated Exposure Uptake Biokinetic (IEUBK) model for lead were analyzed extensively in Chapter 4 of the *Five Year Review for the Populated Areas of the Bunker Hill Superfund Site* (TerraGraphics 2000). The relationship between blood lead, soil, and dust lead levels and the effectiveness of the remedial actions at the BHSS were examined by a variety of techniques in the five-year review. A brief summary of the methods and findings follows.

Two major health response actions, the Lead Health Intervention Program (LHIP) and the Populated Areas soil cleanup, were undertaken to reduce blood lead levels since 1988. Analyses suggest that these programs are largely responsible for the decreases in blood lead levels observed over the past eleven years. The LHIP has monitored children’s blood lead levels since 1988, prior to the cleanup of residential properties beginning in 1989 and the two Records of Decision (ROD) cleanups commencing in 1991 and 1994. The LHIP seeks to reduce intake of lead by modifying people’s behavior through educating parents and children in the community. The LHIP essentially advises parents how to help their children ingest less dirt through improved hygiene. This concept has been used nation-wide, and has been known since the 1970s to be effective.

Remedial actions seek to reduce intake of lead through cleanup, control, and elimination of sources of lead. The remedial program effectively replaces contaminated soils and dusts throughout the community with clean dirt. The Populated Areas remedial activities are partially completed. Smelterville was finished in 1997 and no home yards now exceed the 1000 mg/kg yard soil lead Remedial Action Objective (RAO). In 1999, about 20% of Kellogg, 44% of Wardner, 17% of Page and 5% of Pinehurst homes have soil levels remaining above 1000 mg/kg lead.

Since the inception of remedial activities in 1989, mean blood lead levels have decreased by 70% (14.2 to 4.3 µg/dl) in Smelterville, 58% in Kellogg (10.8 to 4.5 µg/dl), 55% in Wardner (11.8 to 5.4 µg/dl), 67% in Page (12.5 to 4.1 µg/dl); and 33% in Pinehurst (7.4 to 5.0 µg/dl). The RAO for blood lead levels requires that no more than 5% of children exceed 10 µg/dl and that no more than 1% exceed 15 µg/dl. The percentage of children exceeding 10 µg/dl has decreased from 1989 to 1999 by 78% to 4% in Smelterville, 52% to 6% in Kellogg, 57% to 0% in Page, 54% to 11% in Wardner, and 29% to 9% in Pinehurst, although Pinehurst showed 3% above 10 µg/dl in both 1997 and 1998. The incidence of blood lead levels exceeding 15 µg/dl has decreased from 1989 to 1999 by 42% to 2% in Smelterville, 22% to 0% in Kellogg, 36% to 0% in Page, 31% to 0% in Wardner, and 5% to 2% in Pinehurst.

The LHIP screening of the at-risk population for high blood lead levels and providing follow up services that have substantially reduced blood lead levels among those children has been successfully implemented. Detailed analysis of school records for the 1998-99 school year indicate that the door-to-door survey identified 88% of all 9-month through 9-year old children in the BHSS. The parents of two-thirds of these children elected to participate in the LHIP. Blood lead samples were successfully obtained from 88% of the participants or 375 children. This resulted in the LHIP obtaining samples from 51% of all the children identified in school records, or 68% of those identified in the door-to-door effort. Of those families that declined to participate in 1998, 13% indicated their children were previously tested and did not have a problem, 11% were concerned with the trauma of drawing a venous blood sample from young children, 52% indicated the LHIP was unnecessary at this time, 14% would not specify a reason, and 10% indicated they had recently moved into the area or were planning to leave.

These results are typical of the last eleven years, although refusals have increased in recent years as environmental exposure, blood lead levels, and the number of children at-risk have declined. More than 4000 blood lead samples have been drawn from children. In total, 372 children were targeted for follow up services and 317 or 85% were completed. Each year about half of the participating children have blood lead measurements from the previous year. As a result, this database is large enough and sufficiently representative of the population to support analysis of the blood lead to soil/dust lead relationship and the effectiveness of the remedial actions.

The various sources of lead and the routes by which children are exposed are also discussed. Lead from contaminated soils and dusts are the primary source of lead poisoning at the BHSS. Young children are at greatest risk because of hand-to-mouth activities. These children crawl and play on floors and soils, contaminated dusts adhere to their hands and toys. Children then often place their hands and toys in their mouths, and swallow the dirt. Older children access other contaminated soils outside their home, as they begin to move around the neighborhood and community.

Regression analysis were accomplished to determine the basic relationship between blood lead and soil and dust lead levels. These results suggest that blood lead levels are related to both soil and house dust and that contaminated soil from the overall community, the immediate neighborhood and the home yard all independently contribute to blood lead. The slope or ratio of blood lead decrease per unit of soil/dust lead concentration reduction is about 0.9 μg lead/dl blood per 1000 mg lead/kg dust, and from 0.3 to 2.5 μg lead/dl blood per 1000 mg lead/kg soils. These slopes are consistent with the lower range of similar values from the literature observed at other sites.

More sophisticated statistical analyses (mixed model) were applied to repeated blood lead measurements, or those children sampled in consecutive years. Many of the differences among children are controlled if the same child is examined from year to year, and any blood lead changes related to modifications in that particular child's environment can be examined. These results show that all children benefitted from the community-wide cleanup efforts through lower blood lead levels. Typical two-year old blood lead levels were reduced more than 5.0 $\mu\text{g}/\text{dl}$

through remediation of community and neighborhood soils and consequent dust lead level decreases. Children who had their yard remediated showed additional blood lead reductions of about 1.7 µg/dl in the following year. Children who received a nurse's visit through the LHIP experienced an even greater reduction, averaging about 4.0 µg/dl for the typical recipient over the eleven year period. These effects continue into later years, further reducing blood lead levels in subsequent surveys.

Structural equation analysis is used to examine the pathways or routes by which lead in soils reach children and is absorbed in the blood. These results suggest that typically about 40% of the blood lead due to soil and dust comes through house dust, about 30% from the greater community soils and 30% from the home and immediate neighborhood. Additionally, about 50% to 60% of the lead in house dust due to soils also comes from the greater community with the remainder from the yard and neighborhood. Together with results from analysis of soil/dust lead relationships, these findings suggest that 60% to 80% of lead in both children's blood and house dust derives from soils. Typical house dust concentrations in 1989 and 1999 were about 1400 mg/kg and 600 mg/kg, respectively. Analysis of dusts from similarly situated homes in northern Idaho outside the mining district suggest that about 200 mg/kg to 400 mg/kg of house dust lead is associated with sources other than soil, such as lead paint or residual contamination in structures and carpets. At the conclusion of the soil remediation program, house dust levels are estimated to average about 400 to 500 mg/kg and typical blood lead levels are predicted to be between 3 and 4 µg/dl.

Historic lead intake rates were calculated based on the percentage contributions of the soil and dust sources suggested in the structural equations analysis. These intakes estimate how much lead a typical child ingested each day from house dust and community-wide, neighborhood and home yard soils for the last eleven years. These intake estimates correspond well with observed blood lead levels and help to explain how blood lead levels have changed in response to soil cleanup activities. Lead intake, and consequently, blood lead levels decreased markedly in the first three years (1989-1991) of cleanup as most children's home yards were remediated in the high risk cleanup program. Intake rates and blood lead levels then stabilized from 1992-1996 as more children moved to contaminated homes on the site, offsetting gains in remediation. This stalemate was broken in 1997 as area wide yard removals greatly diminished the number of contaminated home yards and neighborhoods that families could move into. Intakes and blood lead levels have both gradually decreased to historically low levels since 1997.

The intakes calculated above were used in the IEUBK model for lead. IEUBK results suggest that the dose/response rate for blood lead due to soil and dust lead is less than that expected. The response rate or decrease observed in blood lead per 1000 mg/kg soil and dust is about 60% of default values expected at a typical site. This result is similar to the assumptions used in developing the cleanup strategy and establishing the RAOs for the site. This suggests that when complete, the cleanup strategy, devised in 1990, will be successful in reducing blood lead levels to acceptable criteria. However, based on default response rate parameters suggested by the U.S. EPA, the soil RAO may not be adequate to achieve the blood RAO.

Site-wide Trends in Lead Intake 1988-1998

Typical lead intake from soil and dust sources can be estimated by multiplying soil and dust consumption rates by the respective lead concentrations in each media. This was accomplished for each child for each year assuming a typical combined soil/dust consumption rate of 100 mg/day. Four soil and dust partition scenarios were assumed. Three dust:soil partition scenarios have been applied in the Integrated Exposure Uptake Biokinetic Model (IEUBK) analyses in previous reports and analyses. Those were i) the IEUBK default 55:45 house dust:yard soil partition that assumes that 55% of a child's intake derives from household dust and 45% from residential yard soils, ii) a 40:30:30 house dust:yard soil:community soil partition that assumes that 40% of children's soil/dust ingestion derives from house dust and 30% equally from both home yard and community-wide soils, and iii) a 75:18:7 partition that assumes the child's soil and dust ingestion derives predominantly from house dust, with the remainder proportionately from yard soils and community soils, respectively.

Each of these partitions has been evaluated in previous dose-response analyses in this project as method of encompassing plausible intake rates from soils and house dust. The community-wide geometric soil lead concentrations are used to represent the community soil component in these analyses. The fourth partition added for this report is the 42% house dust / 27% community-wide / 19% neighborhood / 12% yard soil partition suggested by the structural equations analysis. These results are most similar to the 40:30:30 pre-remediation partition noted in historic analyses.

Tables Q4.22a-d through Q4.25a-d summarize the results and trends in estimated lead intake for resident children from soil and dust sources for each year by community and site-wide. All tables and Figures in this appendix are numbered to correspond with similar presentations in Section 4 of the *Five Year Review for the Populated Areas of the Bunker Hill Superfund Site* (TerraGraphics 2000). These results show the combined effects of the high-risk targeting program for yard soils and the portion of the population continuing to live on contaminated yards. These tables show that all the partitions result in similar patterns of decline in overall soil and dust intake estimates over the past decade.

The largest decreases in estimated site-wide intake rates were achieved from 1989-1990 to 1993-1994. Pre-remediation arithmetic mean intake rates were estimated at 250 to 270 $\mu\text{g/day}$ site-wide under the various scenarios. During the first year of remediation 1989-90, intakes decreased by 40-50% to 140 to 155 $\mu\text{g/day}$ lead. Another 20-30% reduction was achieved in 1990-1991 to typical levels of 105-120 $\mu\text{g/day}$ depending on the scenario. From 1991 to 1992 those partitions dominated by house dust showed a 5-15% decrease that was marginally significant. Under the 40/30/30 and default scenarios the 1991-1992 change was not significant in Kellogg. Intake estimates for 1991-1992 were in the 100-125 $\mu\text{g/day}$ range for Kellogg and Smelterville. From 1992 to 1993 another 15-20% reduction was achieved in all partition scenarios that was highly significant. By 1993, site-wide estimated intake rates were around 80 $\mu\text{g/day}$ or decreased by more than 70% since 1988-89. In 1993-94, a 5 to 10% reduction was noted that was marginally significant ($p=0.003-0.02$) with site-wide intake rates decreasing to 70-80 $\mu\text{g/day}$. Geometric

mean intake rate estimates show a similar pattern with means reaching 60 $\mu\text{g/day}$ by 1994.

No significant change in typical site-wide intake rates has been noted since 1994, excepting a slight increase in Smelterville in 1998 associated with low dust lead concentrations in a small number of dust samples in 1997. Gradual decreases, however, have occurred as the area-wide cleanups have progressed and site-wide lead intake estimates were in the 55 to 70 $\mu\text{g/day}$ in 1998.

These results are similar to those for blood lead levels in Table Q4.6a-d. Figure Q4-11 contrasts site-wide intake rates and blood lead levels for 1989-1998. All of the dust/soil partitions examined show significant site-wide reductions in estimated lead intake from soil and dust were achieved in 1989-1990, 1990-1991 and 1992-1993. These are the same years in which significant decreases in blood lead levels were also noted site-wide. No significant change in estimated intake rates was evident under any partition scenario for 1994-97 (except Pinehurst in 1994). Similarly, there was little change in mean blood lead levels during those same years. Increases in site-wide blood lead levels were noted in 1991-1992 and 1993-1994. Changes in intake rates were not-significant in those years for those partitions with higher portions of soil and were marginally significant ($p=0.02-0.03$) for those dominated by house dust. Gradual decreases in both blood lead levels and estimated intake rates have been evident since 1996 as area-wide remediation continues.

Integrated Exposure Biokinetic Model (IEUBK) Analysis

Overview

Determining those soil/dust partitions, intake rates, and structural equation model forms that best describe this population were further assessed through biokinetic analysis. The IEUBK Model for lead that has been applied to the BHSS repeatedly in past analyses. Cleanup criteria for the site were developed using the original version of the IEUBK for lead developed by the USEPA Office of Air Quality Planning and Standards (OAQPS) in 1986. The basic strategy of the analysis conducted during the Populated Areas RI/FS simulated different cleanup scenarios for yard soils. The IEUBK Model was used to estimate resultant blood lead levels, and those were compared to the site RAOs to select a cleanup action level.

The analysis concluded that, in order to meet the RAOs of 95% of the childhood population below 10 $\mu\text{g/dl}$ blood lead, with no (nominally <1%) children exceeding 15 $\mu\text{g/dl}$:

- All yards with soil concentrations greater than 1000 mg/kg lead must be replaced with soils containing less than 100 mg/kg lead;

- The geometric mean lead concentration of all yards in any community must be less than 350 mg/kg; and
- House dust lead levels must decrease to concentrations similar to those in post remediation yard soils.

In the original RI/FS analysis conducted in 1990, the default soil and dust ingestion/absorption parameters of the IEUBK Model were substantially decreased for the projections to conform with observed site blood lead levels. The 1988-89 data available at that time suggested that the IEUBK default parameters overestimated absorption of soil/dust lead by a factor of about two.

The original OAQPS IEUBK Model's default parameters were adjusted from a general assumption of about 100 mg/day soil ingestion with 30% absorption to 70 mg/day and 20% absorption for the 1989 analyses. This adjustment had the effect of predicting an acceptable action level of 1000 mg/kg rather than a value less than 500 mg/kg, that would have been predicted under the default parameters. Since the RI/FS analyses were conducted, several revisions to the IEUBK Model have been released by the USEPA, and ten years of additional site data have accumulated. These data have been analyzed using both default and adjusted intake and absorption parameters and alternate dust:soil partitions to assess any changes in model performance or site dose-response relationship (TerraGraphics 1993, 1996, 1997, 1998).

Applying the IEUBK Default Parameters

Several community and batch-mode applications were run using the existing blood lead environmental exposure database matching children's observed blood, soil, and house dust lead concentrations. IEUBK model default parameters were used in each case, with the exception of soil and dust lead concentrations. Observed house dust and yard soil lead values were used when available. If the house dust value was missing, the geometric mean house dust lead concentration for that community and year was substituted. Missing yard soil lead values were replaced with the geometric mean pre-remediation community-wide yard soil lead concentration. If both house dust and yard soil lead values were missing, the observation was not included in the analyses. Data available for 8- and 9-year-old children were included by assigning an age of 84 months to these observations.

Three dust:soil partition scenarios were applied in the initial IEUBK analyses. Those were i) the IEUBK default 55:45 house dust:yard soil partition that assumes that 55% of a child's intake derives from household dust and 45% from residential yard soils, ii) a 40:30:30 house dust:yard soil:community soil partition that assumes that 40% of children's soil/dust ingestion derives from house dust and 30% equally from both home yard and community-wide soils, and iii) a 75:18:7 partition that assumes the child's soil and dust ingestion derives predominantly from house dust, with the remainder proportionately from yard soils and community soils, respectively. Each of these partitions has been evaluated in previous dose-response analyses at the BHSS. The community-wide geometric soil lead concentrations are used to represent the community soil

component in these analyses.

Tables Q4.26 through Q4.28 and Figures Q4-12 through Q4-14 summarize predicted and observed blood lead levels, geometric standard deviations, and percent to exceed RAOs for the period 1988 to 1998, respectively, for Kellogg, Smelterville, and site-wide for each partition scenario. These results are for all ages in the batch mode applications.

Predicted blood lead levels: Table Q4.26 and Figures Q4-12a-c show predicted blood lead levels for 0-84 month-old children. These model runs vary only in soil and house dust lead concentrations as observed in the annual blood lead surveys and the dust:soil partition. Model default values for air, diet, drinking water, and maternal contribution were used. Several of the communities have small numbers of observations and assessment of the effectiveness of model predictions is limited. Additionally, the summary statistics reported in these tables may not agree with those presented in earlier sections of the report due to the deletion of incomplete observations from the IEUBK analyses.

The model results show little difference in predicted blood lead levels among the three dust:soil partition scenarios. This similarity is likely due to the predominance of house dust in each scenario and the apparent relationship between community-wide soils and house dust lead concentrations. All three scenarios seem to over-predict observed blood lead levels by about 12% to 88% over the ten year period.

Figures Q4-12 show that, prior to effects of the yard remediation program, the IEUBK model significantly over-predicts observed blood lead levels. This was noted in 1990 and was the basis for adopting the 70 mg/day ingestion and 20% absorption parameters used in the supporting analyses conducted in the Feasibility Study. However, as the Yard Remediation Program progressed, the degree of over-prediction by IEUBK default parameters decreased. In 1988-89 the effect was nearly 2-fold (i.e., 60-90% over-prediction). Estimated intake rates for lead from soil and dust were near 300 $\mu\text{g/day}$. From 1990 to 1993, exposure profiles and estimated intake rates were in transition to 70-80 $\mu\text{g/day}$ in 1994. By 1993 the effect was about 25-55% over-prediction. From 1994 through 1998, over-prediction ranged from 7% in 1997 to 57% in 1995. In other years, over-predictions were near 20%.

These observations suggest that the USEPA Default IEUBK Model may be over-predicting absorption from soil and dust sources on the site by about 20 to 25%. Over these years the over-prediction ranged from 7% to 88%, averaging about 25% for the period (i.e., the observed value was about 75% of the predicted value). However, it should be noted that observed blood lead levels may be suppressed due to lowered soil and dust ingestion rates associated with LHIP efforts. As a result, it is possible that the degree of over-prediction could be significantly less if the population was not pre-conditioned by intervention and education efforts.

Variance in blood lead level estimates: There are differences in predicted geometric standard deviations (gsd) among the three dust:soil partitions that also vary for different cities. Table

Q4.27 and Figure Q4-13 show predicted and observed geometric standard deviation for Kellogg, Smelterville, and site-wide scenarios, respectively.

Two different predicted gsd's are shown in these tables. The first geometric standard deviation refers to the variation in *community population* estimated blood lead levels for individual homes by batch mode applications. This is the geometric standard deviation associated with the geometric mean for the individual blood levels predicted for each home in the community data base. This gsd reflects the variance associated with soil and dust lead concentrations in the community and age-specific response, as the model is run for all ages and the results are aggregated. This value should not be confused with the *individual* geometric standard deviation used in the community mode IEUBK model. The default gsd value of 1.6 was applied to the individual blood lead estimates to develop a distribution of probable blood lead levels for each individual situation estimated in the batch procedure. These individual distributions were then aggregated and an overall gsd was determined for the entire distribution. The *overall* geometric standard deviation refers to the distribution of blood lead levels (predicted or observed) across each community and reflects variation in exposure among individual situations and age within each community, as well as the potential variation in individual response.

The community predicted gsd is shown in Figures Q4-13a-c. The latter or overall gsd can be compared to the observed geometric standard deviations for the population in Figures Q4-13d-f. Observed gsd's have increased gradually from values near 1.6 in 1990 to more than 2.0 (Site-wide, and 1.9 in Kellogg) in 1993 as the cleanup has progressed and have stabilized near 1.8 in recent years. Predicted gsd's estimated by the various soil and dust partitions followed a similar pattern, but tended to over-estimate observed values in Kellogg and site-wide prior to 1993, and have generally over-estimated gsd's in Smelterville through the entire cleanup.

As there is little reason for the individual gsd to change, most of the temporal differences can likely be attributed to change in exposure variable distributions. Two factors that influence the distribution of individual soil exposures are important to note. Those factors are mobility in the population and the manner in which the cleanup was accomplished. Mobility in the childhood population has had an important effect on exposure profiles for the community. Between 1989 and 1991, overall blood lead levels in young children were reduced by nearly 40% as the percentage of children on contaminated yards was reduced from more than 80% to 25%. However, from 1991 to 1996 the number of children on contaminated yards was unchanged, even increasing in some years. Despite the efforts of the high-risk yard program, there were no significant gains in reducing the number of children at risk since 1991, until area-wide remedial activities were completed in Smelterville in 1995-96. As a result, the only significant exposure reductions achieved population-wide in 1991 to 1996 were overall decreases in community-wide soils and house dust lead concentrations being achieved through the general cleanup.

The increase in population geometric standard deviation observed in this period is likely in response to the bimodal distribution of yard soil exposures that evolved during the cleanup. The majority of children across all age groups have been in homes with less than 100 mg/kg soil

exposures since 1991. The remainder of children, usually those new to the home in the previous year, were on highly contaminated yards. Site-wide, the three scenarios have been fairly consistent in predicted geometric standard deviations, with the default scenario predicting the largest variation in blood levels.

Predicted Toxicity Levels: Table Q4.28 and Figure Q4-14a-c show predicted and observed lead toxicity or percent to exceed 10 $\mu\text{g/dl}$ estimates for the various model runs. Percent toxicity predictions consistently exceed observed values, as expected, because mean blood lead levels are overestimated for most years. However, in those years when the model best predicted the observed values (1994, 1996, 1997, and 1998), percent to exceed were well represented site-wide, slightly over-predicted in Kellogg and, conversely, under-predicted in Smelterville since the completion of remedial actions.

Default Model Discussion: The default application of the IEUBK model has over-predicted blood lead levels and percent of children exceeding 10 $\mu\text{g/dl}$, since the beginning of cleanup activities. However, the degree of over-prediction has decreased as the cleanup has progressed and intake rates and blood lead levels have been reduced. Predicted exceedances in Smelterville since the completion of cleanup have been similar to observed levels. These results suggest that the slope of the dose-response relationship between blood lead and soil and dust lead may have increased.

There are several factors that could account for this apparent change. Three primary hypotheses for why the dose-response rate has increased as the cleanup proceeded are: i.) demographic changes in the population (i.e., increased soil and dust ingestion rates reflective of demographic and behavioral changes), ii.) changing bio-kinetic relationships at lower blood lead levels (i.e., lead bio-kinetics are not linear and ingested lead is more efficiently absorbed at lower concentrations), and iii.) changes in source characteristics (i.e., as the cleanup proceeds the dominant sources change and differing chemical or physical characteristics affect ingestion or uptake rates).

IEUBK Application of Structural Equation Model Results

Estimating Effective Bioavailability: The three hypotheses discussed above, respectively, suggest that the apparent change in dose-response rate is due to i) higher intake rates, ii) non-linear biokinetics, or iii) increasing bioavailability. Although it is not possible with this database to discern which of these effects is dominant, the latter possibilities can be examined using the results of the structural equations analysis in the IEUBK model. The relationship illustrated in Figure Q4-11 can be used to estimate the aggregate bioavailability of soils and house dust. This is accomplished by estimating blood lead uptake by dividing observed blood lead levels by the Harley-Kneip age-specific coefficient for lead absorption. Age-specific soil and dust intake rates can be estimated using default ingestion rates from the IEUBK and the soil/dust partition suggested by the structural equations analysis. Aggregate bioavailability of soils and dust can then be estimated by dividing the uptake by the intake.

This analysis is similar to the methodology used to estimate the reciprocal clearance coefficient for lead in earlier IEUBK applications at this site (JEG, et al. 1989; USEPA 1990). However, prior to estimating the effective bioavailability, that portion of lead absorption due to sources other than soils and dusts (i.e., diet, drinking water, and air) must be considered. The calculation can be adjusted to partially account for these factors using the relationship identified in the structural equations analysis for lead. The uptake estimate can be adjusted to reflect only that portion of blood lead related to the soil and dust intake by subtracting the intercept term in the blood lead equation from the observed blood lead and using the resulting difference in the uptake calculation. This corresponds to deducting the other dietary, air and drinking water component uptakes from the absorbed lead. This was accomplished for the site-wide database and Table Q4.29 and Figure Q4-20 summarizes estimated arithmetic and geometric mean bioavailability for the years 1988 to 1998.

The results show that arithmetic mean bioavailability was 17% (or about half the 30% default rate, as used in setting the RAO) in 1988. This value corresponds to the reduced dose response rates used in developing the RAOs. This value then ranged near 22% from the beginning of the cleanup in 1989 through 1995 as was noted in earlier analysis (TerraGraphics 1997). Since 1996, arithmetic mean bioavailability has been near the default level of 30%. The geometric mean bioavailability estimate is lower. The geometric mean was near 14% in 1988 (also near half the default), ranged near 18% in the 1989-95 time period and about 21% since 1996.

This analysis assumes the ingestion rates and underlying bio-kinetics of the IEUBK model. The effective bioavailability is then estimated based on relating observed blood lead absorption and intake rates suggested by the structural equations model. Assuming these parameters apply, assessing the change in bioavailability differs depending on whether the arithmetic or geometric mean is evaluated. Arithmetic mean estimates suggest a marked change in bioavailability to near the 30% default concentrations in 1996. This corresponds to the area-wide cleanups and the resulting effect of re-initiating the downward trend in the percent of children on contaminated home yards. This also marks the period that house dusts become more dominant in the exposure profile.

The structural equations model adds support to the latter hypothesis. These model results suggest that as the area-wide cleanup progresses, community and neighborhood soil concentrations are decreased and the predominant lead source changes from community-wide soils toward house dust. The main pathway to children becomes increasingly dominated by the house dust route and sources other than soil become greater relative contributors. These other sources may be paint or residual smelter contaminants that are more available, increasing aggregate bioavailability. There is little reason to suspect that there are significant differences in chemical or matrix effects between the yard soil and community-wide soil lead. However, there are reasons as to why house dusts would be more bioavailable to children than yard soils. House dust particles are smaller and more accessible to young children than soils. As a result, increased bioavailability, increased dermal adherence, and increased ingestion rates are possible explanations for the enhanced response rate. These dusts are available to children year around, more readily adhere to hands, toys and personal

items, and are more prone to absorption by the gut, all other factors being equal. It is also possible that dust ingestion rates have increased as the effectiveness of the health intervention effort has decreased over the years.

Assessing the trend in arithmetic mean bioavailability suggests that blood lead has become more responsive to environmental media concentrations as remediations are completed. The absorption rate has been near the 30% default level since 1996. This suggests that default parameters should be used to predict future compliance with RAOs.

Evaluating the geometric mean bioavailability estimates can lead to a different interpretation. The geometric mean was also near half the 30% default in 1988, as noted. However, the increase noted in 1996 was modest in comparison to the change in the arithmetic mean. Estimated geometric mean bioavailability changed from about 18% to 21%. This change could be due the same factors discussed above, but is not so significant for the bulk of the population. This marked difference in arithmetic and geometric mean estimates suggests that some smaller number of children are responding at much higher rates. These higher response rates could be due to any number of physiological, nutritional, socio-economic, or behavioral causes; or possibly, artifactual due to unaccounted sources.

In any case, it is likely more appropriate to use the geometric mean estimate in evaluating the historic effects of soil and dust exposure in site-specific application of the IEUBK. Using the arithmetic mean results in over-prediction of mean blood lead levels and the percent of children to exceed critical toxicity levels due to the sources in the model. Conversely, use of the geometric mean bioavailability could result in underestimation of mean blood lead levels in the future.

A site-specific application of the IEUBK model was developed for the eleven year period using these results. The 42% house dust:27% community soil:19% neighborhood soil:12% yard soil partition and 18% bioavailability parameters suggested by the structural equations analysis was used. Missing dust lead observations were estimated using the dust lead equation developed in the structural equations model.

Table Q4.30 and Figures Q4-15 through Q4-17 summarize the model results. It should be noted in reviewing the following results that similar results could be obtained by reducing the soil and dust ingestion rate by 40% or several combinations of reduced bioavailability and ingestion rate.

Predicted blood lead levels: Table Q4.30 shows predicted and observed results for two year old and 0-84 month-old children for Kellogg, Smelterville and site-wide, respectively, for all years. This model form reasonably predicts geometric mean blood levels across the site. Both predicted and observed levels have decreased consistently with estimated soil and dust intake rates. Figure Q4-11b shows mean blood lead levels and estimated intake rates calculated by the structural equations 42:27:19:12 partition, similar to Figure Q4-11a for the default model analysis above. This relationship is effectively described by the IEUBK model at the 18% bioavailability level assuming default ingestion rates. Figures Q4-15a-c show predicted and observed values for 0-84

month-old children. Figures Q4-15d-f show similar results for two year-old children. Smelterville results are confounded by few numbers of observations in several years. These figures indicate good correspondence between modeled and observed blood lead levels for this critical segment of the population. Other age groups show similar results, indicating that the 84 month assumption for eight and nine year old children has not significantly biased the outcome predictions.

Variance in blood lead level estimates: Figures Q4-16a-c and Table Q4.30 show observed and the predicted community and overall gsd for all ages for all years and communities. The results are similar to those noted in the EPA Default model applications. Predicted overall gsd exceeded observed levels prior to 1993 and have been near or slightly less than observed levels since. The individual model geometric standard deviation used to estimate individual variation in these analyses was the community mode default 1.6 value. In community mode IEUBK applications the observed gsd is for the community population is consistently under-predicted. Although, community mode results are not shown in these tables, it is important to discuss the estimated gsd.

The under-prediction in the community mode can be resolved by adjusting the individual gsd model input to about 1.8. However, it is not clear whether this adjustment would correctly reflect the exposure-uptake relationship. The under-prediction in population gsd is related to the character and underlying causes for the observed distribution in dose-response. In evaluating the effective bioavailability, a continuing divergence in the estimated arithmetic and geometric means was noted over time. This divergence increased as blood lead and the percent of the population to exceed critical toxicity levels decreased. This suggests that within the population some smaller number of children are responding at higher rates of absorption. This group becomes “more different” as the cleanup proceeds and soil and dust exposures subside. Two possibilities that might explain this divergence are immediately evident. Either these children are more sensitive to the sources included in the model, or they are exposed to sources unaccounted for in the model. If the former is the case, it would be proper to expand the individual gsd to accommodate these response rates. If the latter is true, then the higher blood lead levels are not related to the sources in the model and using an enhanced gsd to predict the response would be incorrect.

In the batch mode application of the IEUBK model, typical (or 50th %-tile) blood lead levels are estimated for each exposure situation (or home) in the community. These results are accomplished for each age group and then aggregated. Resulting means and variances can be calculated from these results by age or for all ages 0-84 months. Although the means calculated by this method are representative of the population, the associated gsd reflects only the variance in exposures and age-specific response. The variance in individual response is not included. As a result, this gsd is not appropriate to use in estimating probabilities of exceeding critical toxicity criteria. This gsd is shown in Figures Q4-16a-c as the *community* gsd. The potential individual variance should also be applied to the typical blood lead estimates. The individual gsd of 1.6 was applied to the batch mode blood lead estimates and the resulting distributions were aggregated for the community/population. These results are shown in Table Q4.30 and Figures Q4-16a-c as the predicted *overall* gsd. Using this value, observed overall geometric standard deviations for the

population were over-predicted in the early years of the cleanup and have been similar to observed community gsd in recent years.

Predicted Toxicity Levels: In the community mode application, the population variance is underestimated by the pathways model as discussed above. As a result, the percent of children to exceed of critical toxicity levels are also under-predicted. This prediction could also be improved by adjusting the individual gsd from the default value of 1.6 to near 1.8. However, the same considerations as to the appropriateness of this adjustment discussed above applies.

In the batch mode, application of the 1.6 individual gsd to the typical blood lead estimates results in an overall gsd near 1.8 and a reasonable approximation of the percent of children to exceed 10 ug/dl throughout the cleanup years. Table Q4.30 and Figures Q4-17a-c show these results for the batch mode reduced bioavailability model. These results show good correspondence between predicted and observed percentage of children to exceed 10 $\mu\text{g/dl}$. Percent to exceed values are well predicted for all three areas and all years prior to 1994. Since 1994, percent to exceed values have been slightly under-predicted. This result is not unexpected. It is anticipated that the IEUBK Model would somewhat under-predict exceedance of the 10 $\mu\text{g/dl}$ criteria in recent years. This is because, follow-up investigations have shown that some high blood levels are due to exposures unaccounted for in the model. The model results would not be expected to predict these excursions.

Those children whose apparent greater response rates confound this analysis are, not coincidentally, those intensively evaluated by the PHD follow-up program. Review of these children's histories since 1996, when suggested increases in effective bioavailability were noted, provides some insight regarding the potential sources of this variation.

These histories show that PHD officials found the majority of these children are socio-economically disadvantaged, highly mobile, with care often provided in multiple locations among extended family or cooperative situations. These children tend to exhibit frequent hand to mouth activity and poor to fair personal and home hygiene. Most were also exposed to high concentration soil and dust sources in play areas or away from their home. Generally, those soil sources identified within the BHSS were areas away from the child's home at locations that had not yet been remediated. These included relatives' and day care yards in un-remediated portions of Kellogg, hillsides, common areas surrounding particular housing complexes and Milo Creek flood debris. Extended recreational activities at contaminated locations and moving from contaminated homes outside of the BHSS has also been noted more frequently in recent years. Several children were noted to be in homes with relatively high dust concentrations. Some were indicated to be in homes with poor interior paint condition.

These observations suggest that the high response rates are due to a number of factors. Frequent hand to mouth activities, poor personal and home hygiene, high house dust concentrations and any paint lead reflected in those dusts are all factors accounted for in the model analysis. It would be appropriate to increase the individual gsd to accommodate these factors in exposure variance.

Those factors related to sources outside the home environment, i.e., flood debris, hillsides campgrounds, un-remediated areas in Kellogg, and contaminated soils in the greater Coeur d'Alene Basin are conditions unrelated to the model predictions.

The batch mode results shown in Table Q4.30 and Figures Q4-17a-c indicate that the IEUBK, utilizing the reduced absorption rate and soil partition factors suggested by the structural equations analysis, is an effective predictor of mean blood lead levels throughout the cleanup process. This methodology is useful in reassessing the cleanup criteria and likelihood that blood lead RAOs will be achieved. However, there are exposure factors unaccounted for in the model constructs. These include other sources of exposure and peculiar conditions that affect individual children leaving them at greater risk. With respect to residential soils and dust, these analyses suggest that the cleanup has been effective in reducing risk to acceptable levels (i.e., those reflected in the RAO) for the vast majority of the population. There are, however, individual situations and additional sources of lead remaining in and around the BHSS putting some children at-risk. Some of these sources will be addressed in upcoming remedial activities. Those problems identified outside the scope of the remediation strategy will need to be resolved on a case by case basis.

Figures Q4-18a-b and Q4-19a-b show plots of observed versus predicted arithmetic and geometric mean blood lead levels, respectively, site-wide for all age groups aggregated for all years, for both the EPA Default and Box Model. In these figures the more recent observations are at the lower left and progress back in time toward pre-remedial conditions at the right. Figures Q4-18b and Q4-19b demonstrate that observed mean blood lead levels are accurately reproduced using the dust: soil partitions factors and effective bioavailability suggested by the pathways analysis. Use of default bioavailability results in over-prediction of observed blood lead levels in earlier years, as seen in Figures Q4-18a and Q4-19a. In recent years at low intake rates, the model results are converging, suggesting that default bioavailability may be becoming more appropriate as exposures and blood lead levels approach acceptable criteria.

It must be remembered that use of the reduced or site-specific absorption rate may or may not be appropriate for future site conditions. Caution should be emphasized because the reduced absorption rate could be either due to reduced bioavailability or ingestion rates or some combination of both. This reduction may reflect temporary modifications in the environment due to ongoing cleanup efforts or behavioral changes due to public awareness associated with the health intervention programs that would not be permanent. In that case, it would be inappropriate to apply reduced factors to evaluations of the long-term risk reduction strategy.

Summary and Conclusions

Quantifying Exposure Pathways: Blood lead and soil and dust pathways were explored through structural equations analysis. These models indicate that from 40% to 50% of the blood lead absorbed from soils and dusts is through house dust with about 30% from community-wide soils and 30% from the home yard and immediate neighborhood (200 foot radius). These relative

contributions agree with findings of earlier studies conducted in the early 1980s and analyses used to develop the cleanup criteria for the site.

The same structural equation models suggest that community-wide soil contribute between 50% and 60% of the soil lead component in house dust with the neighborhood and home yard contributing about 20% each. This results in soils overall contributing about 80% of lead to house dust in the pre-remedial environment and an estimated 50% to 60% post-remedial.

Intake rate estimates generated from the results of the pathways model indicate that typical pre-remediation lead intake rates due to soil and dust were 250 to 270 $\mu\text{g/day}$ site-wide. During the first year of remediation 1989-1990, intakes decreased by 40-50% to 140 to 155 $\mu\text{g/day}$ lead. Another 20-30% reduction was achieved in 1990-91 to typical levels of 105-120 $\mu\text{g/day}$. In 1991-92 only marginal decreases were achieved to the 100-125 $\mu\text{g/day}$ range. From 1992 to 1993 another 15-20% reduction was achieved and estimated site-wide intake rates were about 80 $\mu\text{g/day}$ or decreased by more than 70% since 1988-89. In 1993-94, a 5 to 10% reduction was noted that was marginally significant, with average site-wide intake rates decreasing to 70-80 $\mu\text{g/day}$. Only gradual decreases, however, have occurred since 1994 as the area-wide cleanups have progressed and site-wide lead intake estimates were in the 55 to 70 $\mu\text{g/day}$ by 1998.

Biokinetic Models: Both mean blood lead levels and percent of children to exceed toxicity levels have paralleled the intake estimates. Analyses of these data indicate that the decreasing blood lead levels are consistent with the estimated intake of lead from soils and dusts. The dose-response ratio of blood lead per unit of soil and dust intake seems to be increasing. This suggests that either ingestion rates are increasing, the lead is becoming more bioavailable, the dose-response curve is changing, and/or the baseline sources of lead (other than soils and dusts) are progressively larger contributors.

Application of the IEUBK model for lead continues to indicate that default parameters over estimate resultant blood lead levels, although the magnitude of over-prediction is diminished at lower intake rates in recent years. Application of the model using the soil and dust partitions suggested in the pathways model, IEUBK ingestion parameters, and an effective bioavailability of 18%; accurately predicts geometric mean blood lead levels throughout the eleven year cleanup period.

This model form, however, under-predicts the observed variance in the population blood lead levels and consequently the percent of children to exceed critical toxicity criteria. There are significant questions as to whether the highest blood lead concentrations observed in recent years are due to sources accounted for in the remedial strategy and subsequent IEUBK analyses, or represent peculiar exposure situations.

This application is consistent with the analysis used to develop the cleanup criteria for the existing Populated Areas ROD. Substitution of post-remedial concentrations in this model format indicates blood lead RAOs would be achieved. Application of default mode IEUBK parameters

would continue to predict excessive absorption rates and failure to meet the RAOs.

In either case, some number of exceedances of toxicity criteria can be expected due to sources of lead in the environment that remain unaddressed by remedial activities. Also, exceedance levels for 1-2 year-old children are expected to be greater than 5%, in any case. It is unclear if a model based on conditions observed during the course of the cleanup and associated intervention activities can accurately predict future blood lead levels.

Although observed blood lead trends at the BHSS have improved significantly during site response efforts, the assumptions and Lead Model inputs used to develop the soil and dust RAOs may not be sufficient to achieve the blood RAOs. The remedy may not be protective because of the observed increase in rates of blood lead dose-response or additional unremediated sources of exposure.

Figure Q4-11
Site Wide Intake Rates and Geometric Mean Blood Lead Levels

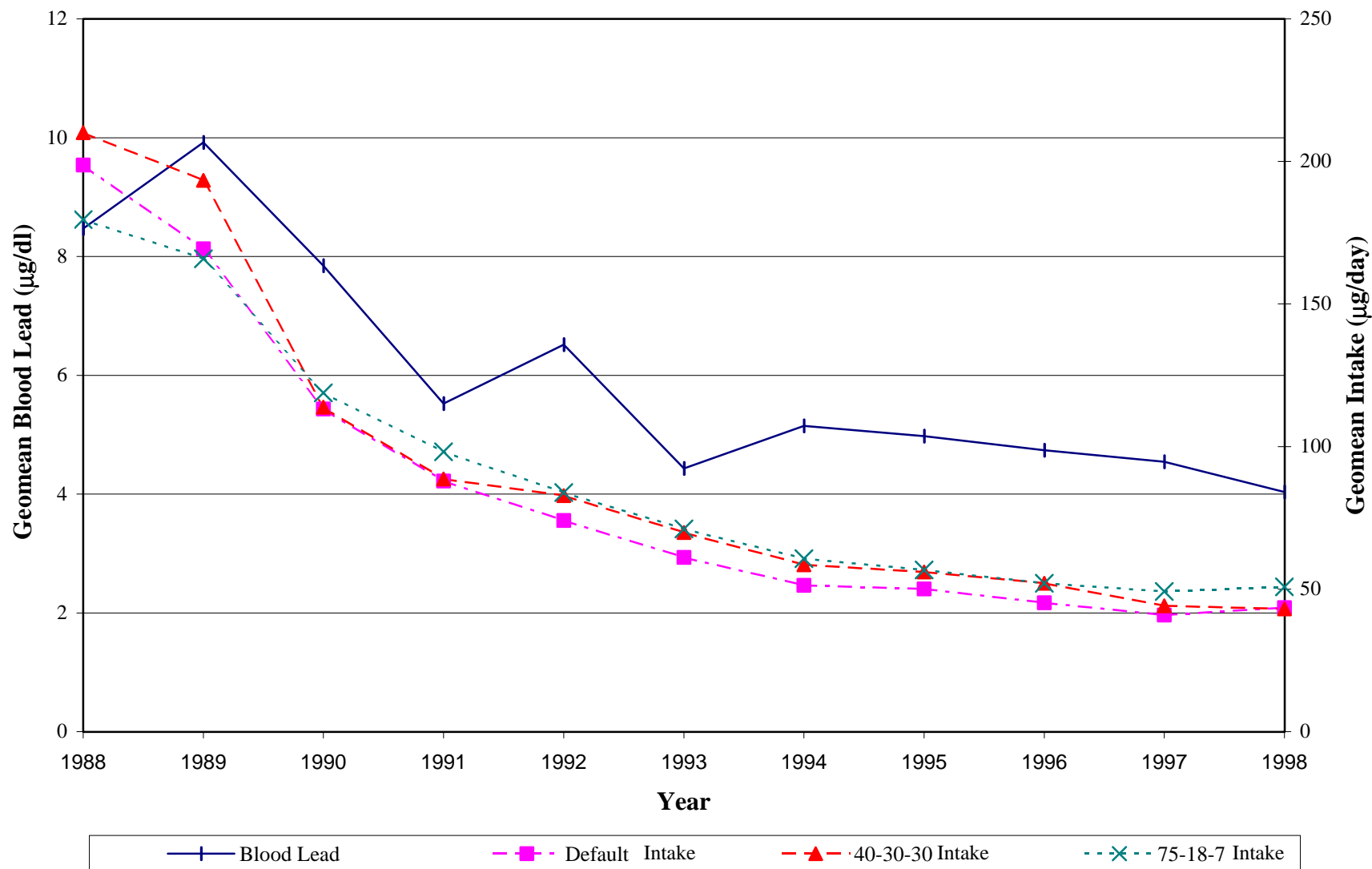


Table Q4.22 Estimated Soil and Dust Lead Intake (Default 55:45 Dust/Soil)¹

Table Q4-22a Site Wide

Year	N	Mean	GeoMean	GeoP-value
1988	70	272	199	-
1989	49	263	169	0.2428
1990	139	154	113	0.0001
1991	162	109	88	0.0028
1992	230	101	74	0.0233
1993	199	81	61	0.0096
1994	203	71	51	0.0248
1995	153	78	50	0.7802
1996	162	68	45	0.2857
1997	100	65	41	0.3536
1998	157	57	43	0.5272
Overall				0.0001

Table Q4-22b Kellogg

Year	N	Mean	GeoMean	GeoP-value
1988	44	314	223.5	-
1989	31	330	204.5	0.6045
1990	68	176	133.3	0.0011
1991	75	126	108.2	0.0757
1992	124	125	91.4	0.1216
1993	111	84	63.7	0.0006
1994	105	75	53.9	0.1210
1995	97	84	57.0	0.6229
1996	107	69	49.5	0.2119
1997	59	73	48.1	0.8206
1998	82	63	47.0	0.8661
Overall				0.0001

Table Q4-22c Smelterville

Year	N	Mean	GeoMean	GeoP-value
1988	21	226	183.7	-
1989	14	162	137.7	0.2170
1990	15	218	186.3	0.3578
1991	27	125	109.5	0.0045
1992	26	76	58.1	0.0006
1993	19	118	84.8	0.1212
1994	35	97	64.5	0.2899
1995	20	118	64.3	0.9896
1996	12	132	46.4	0.4596
1997	15	31	26.9	0.1671
1998	26	41	39.7	0.0026
Overall				0.0001

Table Q4-22d Pinehurst

Year	N	Mean	GeoMean	GeoP-value
1990	46	97	74.8	-
1991	51	82	61.6	0.1612
1992	66	70	58.4	0.6608
1993	55	67	54.1	0.5079
1994	43	41	36.9	0.0022
1995	30	40	30.6	0.1914
1996	37	44	35.9	0.3450
1997	18	80	35.9	0.9986
1998	35	40	34.3	0.8364
Overall				0.0001

¹ assumes dust/soil intake is 55% housedust, 45% yard soil

Table Q4-23 Estimated Soil and Dust Lead Intake (40:30:30)¹

Table Q4-23a Site Wide

Year	N	Mean	GeoMean	GeoP-value
1988	70	259	210	-
1989	49	256	193	0.4517
1990	139	145	114	0.0001
1991	162	106	89	0.0014
1992	226	100	83	0.2872
1993	197	82	70	0.0037
1994	201	71	59	0.0030
1995	151	76	56	0.5353
1996	160	68	52	0.3642
1997	100	63	44	0.0769
1998	153	54	43	0.7760
Overall				0.0001

Table Q4-23b Kellogg

Year	N	Mean	GeoMean	GeoP-value
1988	44	282	221	-
1989	31	294	210	0.7191
1990	68	176	153	0.0023
1991	75	127	116	0.0009
1992	124	124	106	0.2042
1993	111	91	80	0.0001
1994	105	78	66	0.0055
1995	97	87	70	0.4602
1996	107	75	63	0.1854
1997	59	73	54	0.1556
1998	82	62	49	0.4252
Overall				0.0001

Table Q4-23c Smelterville

Year	N	Mean	GeoMean	GeoP-value
1988	21	245	222	-
1989	14	214	197	0.4460
1990	15	218	204	0.6990
1991	27	137	127	0.0005
1992	26	98	92	0.0029
1993	19	115	100	0.5401
1994	33	89	76	0.0990
1995	20	92	52	0.0999
1996	12	100	40	0.5051
1997	15	26	25	0.1778
1998	26	34	33	0.0074
Overall				0.0001

Table Q4-23d Pinehurst

Year	N	Mean	GeoMean	GeoP-value
1990	46	76	60	-
1991	51	66	52	0.2228
1992	62	57	50	0.7066
1993	53	55	47	0.5968
1994	43	36	33	0.0012
1995	28	34	29	0.2679
1996	35	38	33	0.3963
1997	18	65	34	0.8128
1998	31	36	32	0.7103
Overall				0.0001

¹ assumes dust/soil intake is 40% housedust, 30% yard soil, 30% community soil

Table Q4-24 Estimated Soil and Dust Lead Intake (75:18:7)¹

Table Q4-24a Site Wide

Year	N	Mean	GeoMean	GeoP-value
1988	70	271	180	-
1989	49	285	166	0.5716
1990	139	153	119	0.0002
1991	162	118	98	0.0123
1992	226	104	84	0.0182
1993	197	87	71	0.0097
1994	201	76	61	0.0169
1995	151	79	57	0.4020
1996	160	72	52	0.3095
1997	100	80	49	0.5740
1998	153	67	51	0.7430
Overall				0.0001

Table Q4-24b Kellogg

Year	N	Mean	GeoMean	GeoP-value
1988	44	324	200	-
1989	31	359	189	0.7662
1990	68	171	141	0.0263
1991	75	137	124	0.1640
1992	124	121	101	0.0140
1993	111	92	79	0.0017
1994	105	80	66	0.0338
1995	97	88	68	0.7320
1996	107	70	59	0.1206
1997	59	89	60	0.9178
1998	82	75	58	0.8169
Overall				0.0001

Table Q4-24c Smelterville

Year	N	Mean	GeoMean	GeoP-value
1988	21	203	168	-
1989	14	175	147	0.5464
1990	15	215	194	0.4579
1991	27	139	133	0.0031
1992	26	103	84	0.0013
1993	19	124	100	0.3688
1994	33	101	79	0.2628
1995	20	103	70	0.5791
1996	12	176	56	0.5829
1997	15	37	31	0.1753
1998	26	50	49	0.0023
Overall				0.0001

Table Q4-24d Pinehurst

Year	N	Mean	GeoMean	GeoP-value
1990	46	108	79	-
1991	51	85	61	0.0731
1992	62	72	59	0.7033
1993	53	67	54	0.4466
1994	43	44	39	0.0112
1995	28	35	28	0.0210
1996	35	44	36	0.1265
1997	18	97	38	0.8356
1998	31	39	32	0.4653
Overall				0.0001

¹ assumes dust/soil intake is 75% housedust, 18% yard soil, 7% community soil

Table Q4-25 Estimated Soil and Dust Lead Intake (42:27:19:12)¹

Table Q4-25a Site Wide

Year	N	Mean	GeoMean	GeoP-value
1988	70	248	205	-
1989	49	255	196	0.6421
1990	139	139	116	0.0001
1991	162	110	96	0.0046
1992	226	99	87	0.0979
1993	197	83	75	0.0013
1994	201	76	67	0.0290
1995	151	74	62	0.1624
1996	160	68	57	0.1365
1997	100	65	48	0.0437
1998	153	53	45	0.3334
Overall				0.0001

Table Q4-25b Kellogg

Year	N	Mean	GeoMean	GeoP-value
1988	44	274.77	216	-
1989	31	293.6	212	0.8828
1990	68	167.06	156	0.0029
1991	75	130.18	125	0.0001
1992	124	116.57	109	0.0057
1993	111	92.82	88	0.0001
1994	105	81.56	76	0.0021
1995	97	86.08	77	0.8641
1996	107	73.6	68	0.0373
1997	59	74.39	60	0.0896
1998	82	59.75	51	0.0913
Overall				0.0001

Table Q4-25c Smelterville

Year	N	Mean	GeoMean	GeoP-value
1988	21	226	214	-
1989	14	213	203	0.6609
1990	15	212	204	0.9766
1991	27	149	147	0.0001
1992	26	115	110	0.0001
1993	19	119	111	0.9000
1994	33	103	96	0.1913
1995	20	79	60	0.0038
1996	12	105	42	0.2992
1997	15	27	25	0.1391
1998	26	35	34	0.0041
Overall				0.0001

Table Q4-25d Pinehurst

Year	N	Mean	GeoMean	GeoP-value
1990	46	77	63	-
1991	51	64	53	0.1229
1992	62	57	52	0.7879
1993	53	54	48	0.3338
1994	43	39	37	0.0029
1995	28	35	32	0.0875
1996	35	39	36	0.2661
1997	18	69	38	0.7214
1998	31	36	33	0.4254
Overall				0.0001

¹ assumes dust/soil intake is 42% housedust, 27% community soil, 19% neighborhood soil, 12% yard soil

Figure Q4-12a
Predicted and Observed Arithmetic Mean Blood Lead Levels in Two Year Old Children
Default Parameters - Three Dust: Soil Partition Scenarios
Kellogg 1988-1998

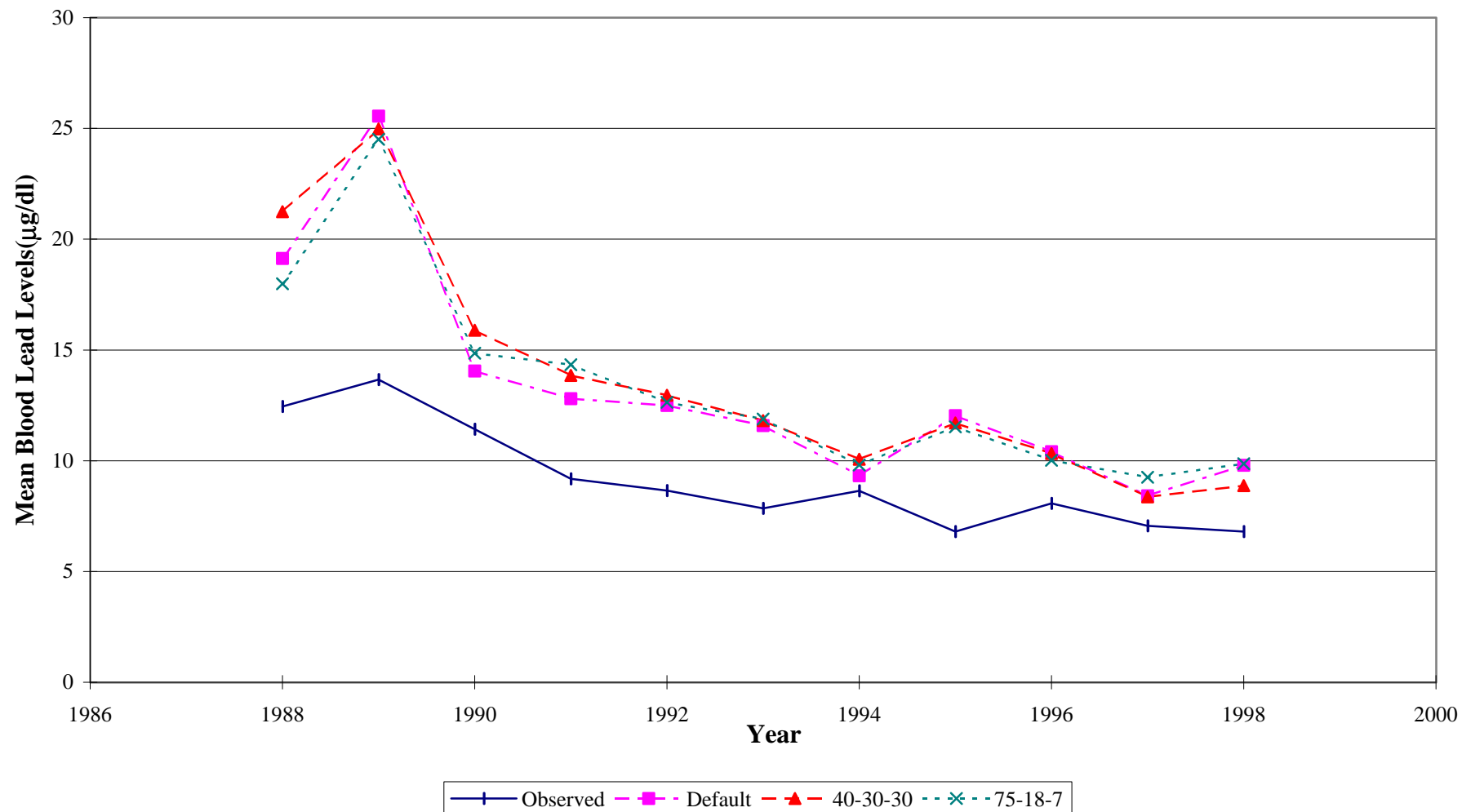


Figure Q4-12b
Predicted and Observed Arithmetic Mean Blood Lead Levels in Two Year Old Children
Default Parameters - Three Dust: Soil Partition Scenarios
Smelterville 1988-1998

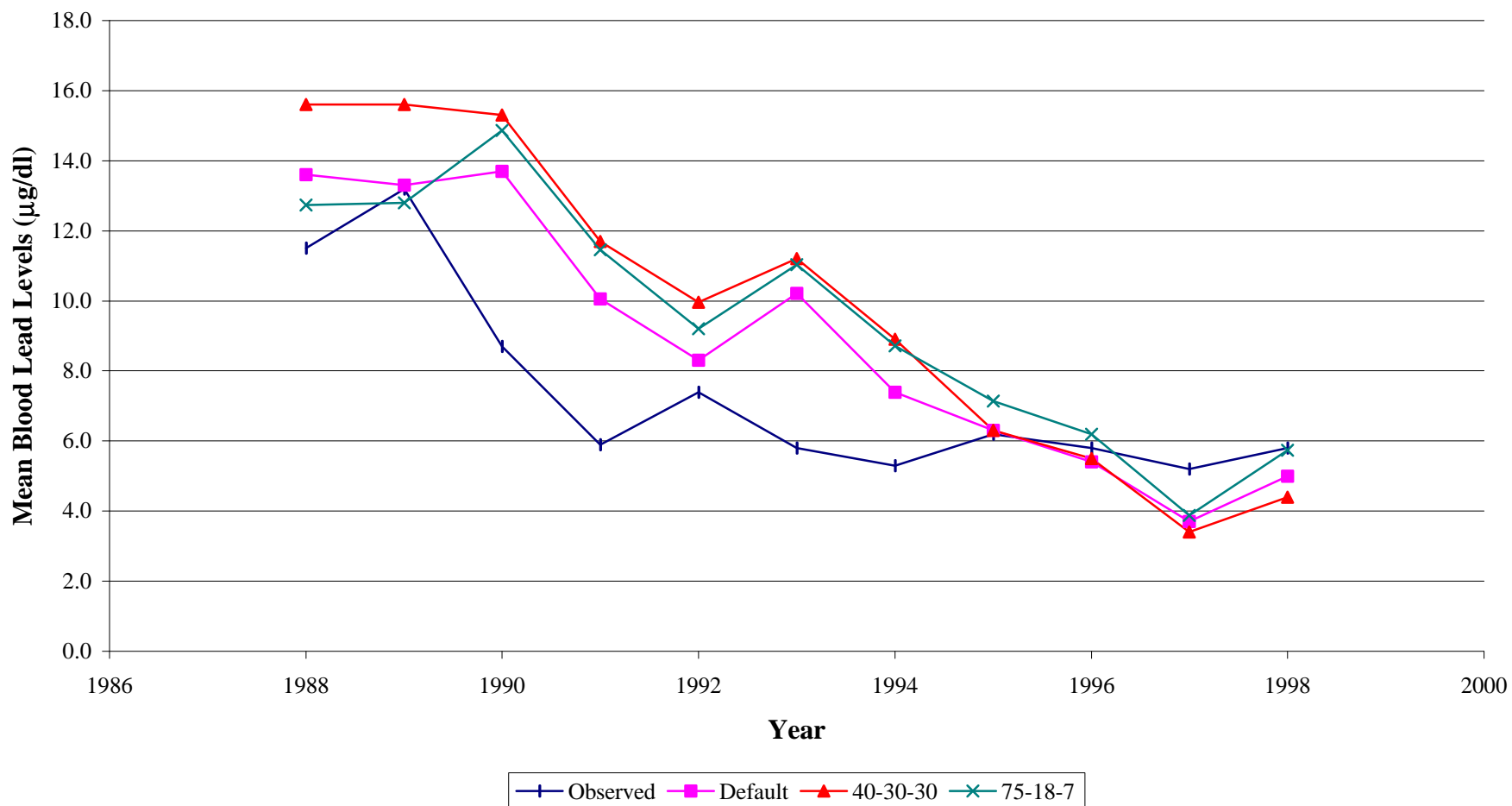


Figure Q4-12c
Predicted and Observed Arithmetic Mean Blood Lead Levels in Two Year Old Children
Default Parameters - Three Dust: Soil Partition Scenarios
Site Wide 1988-1998

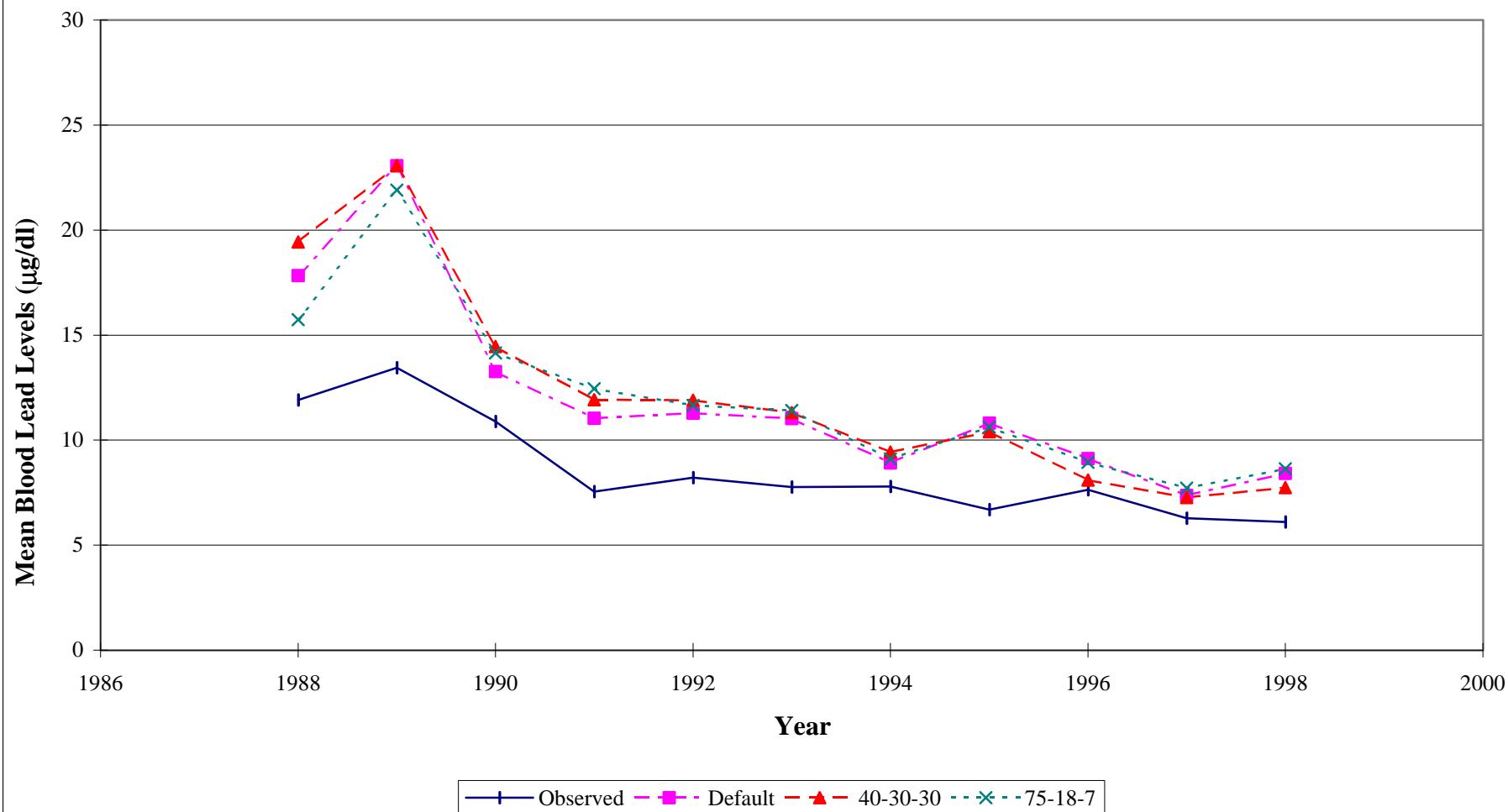


Figure Q4-13a
Predicted and Observed Geometric Standard Deviations Default Parameters
Three Dust: Soil Partition Scenarios
Kellogg 1988-1998

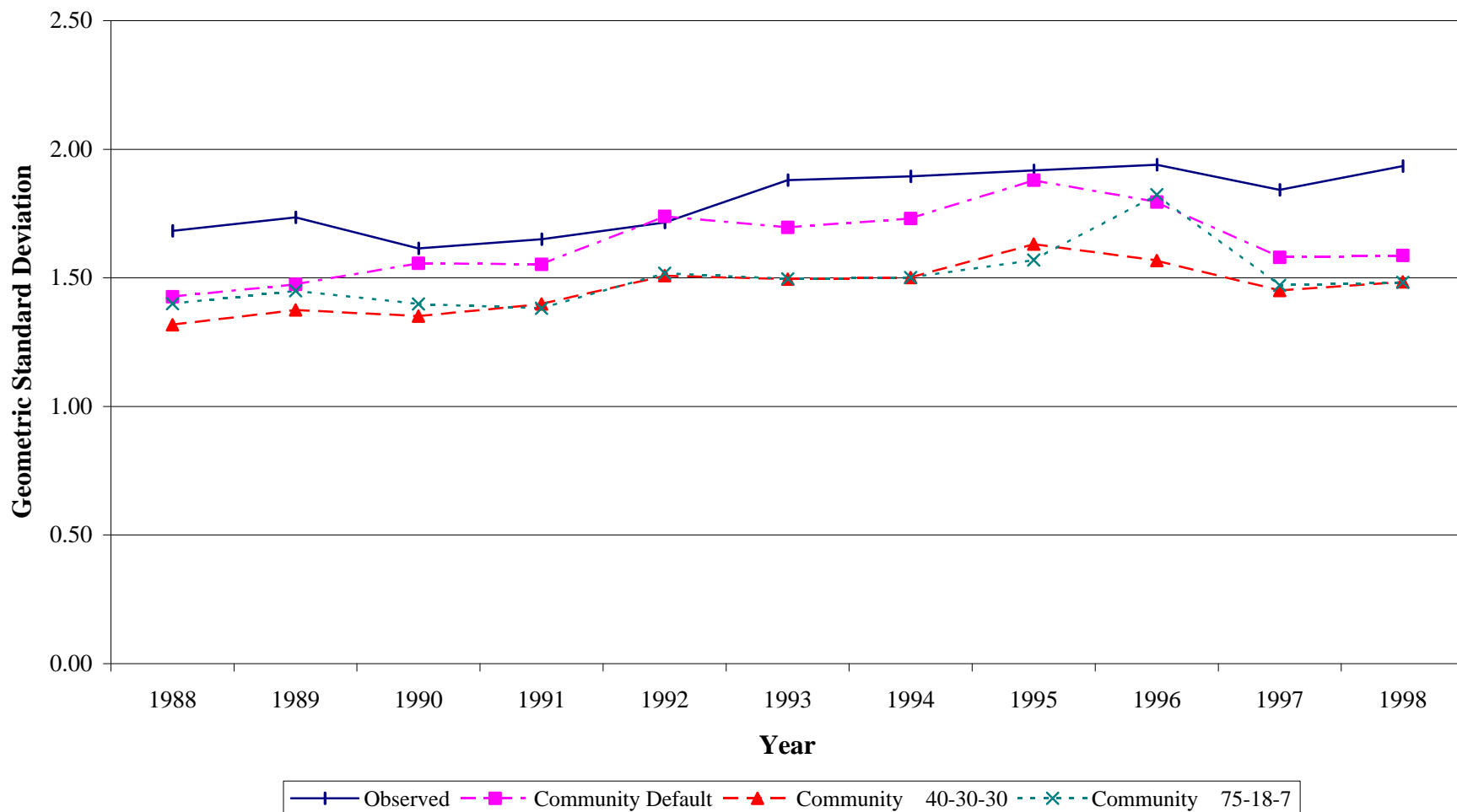


Figure Q4-13b
Predicted and Observed Geometric Standard Deviations Default Parameters
Three Dust: Soil Partition Scenarios
Smelterville 1988-1998

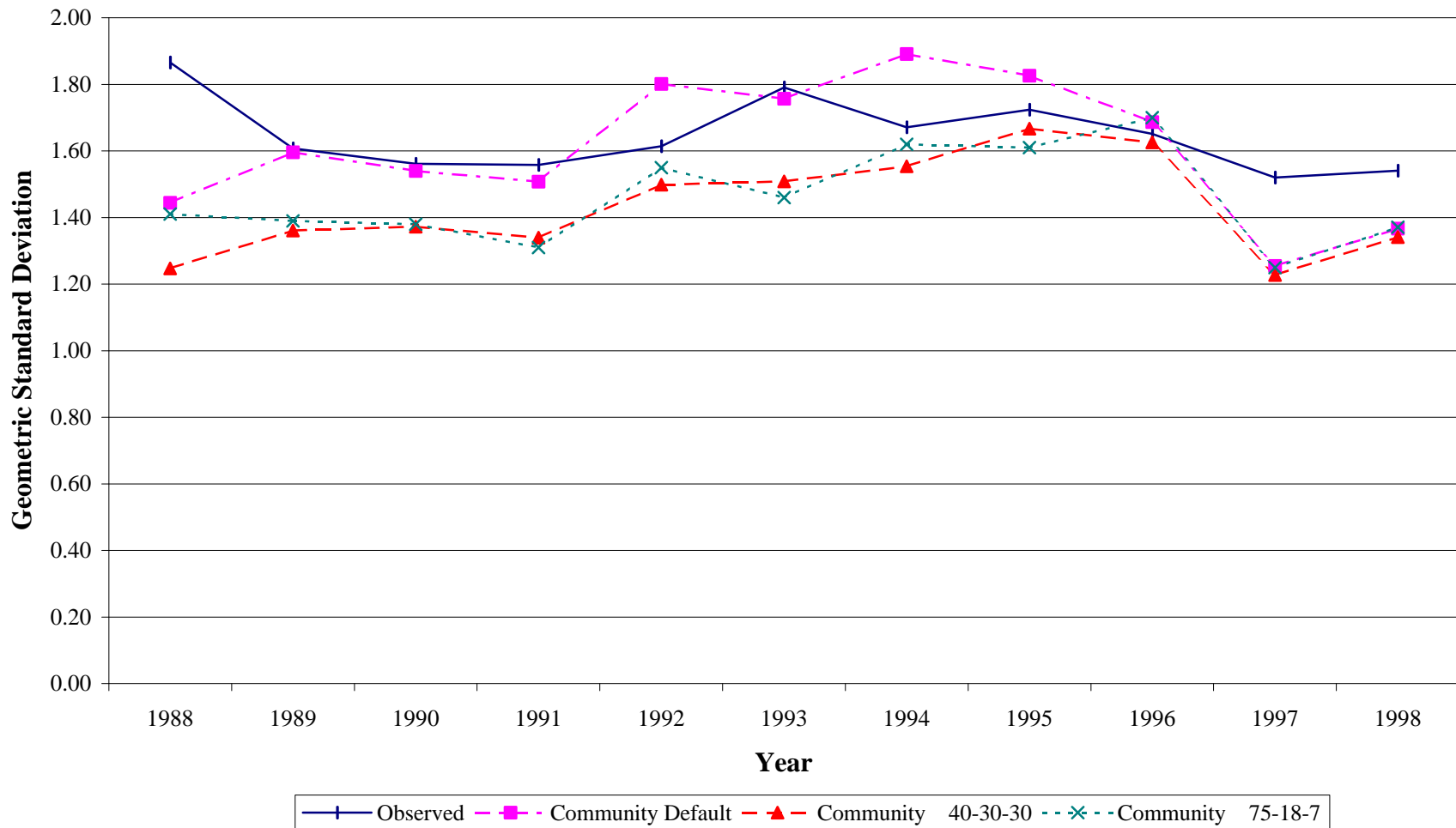


Figure Q4-13c
Predicted and Observed Geometric Standard Deviations Default Parameters
Three Dust: Soil Partition Scenarios
Site Wide 1988-1998

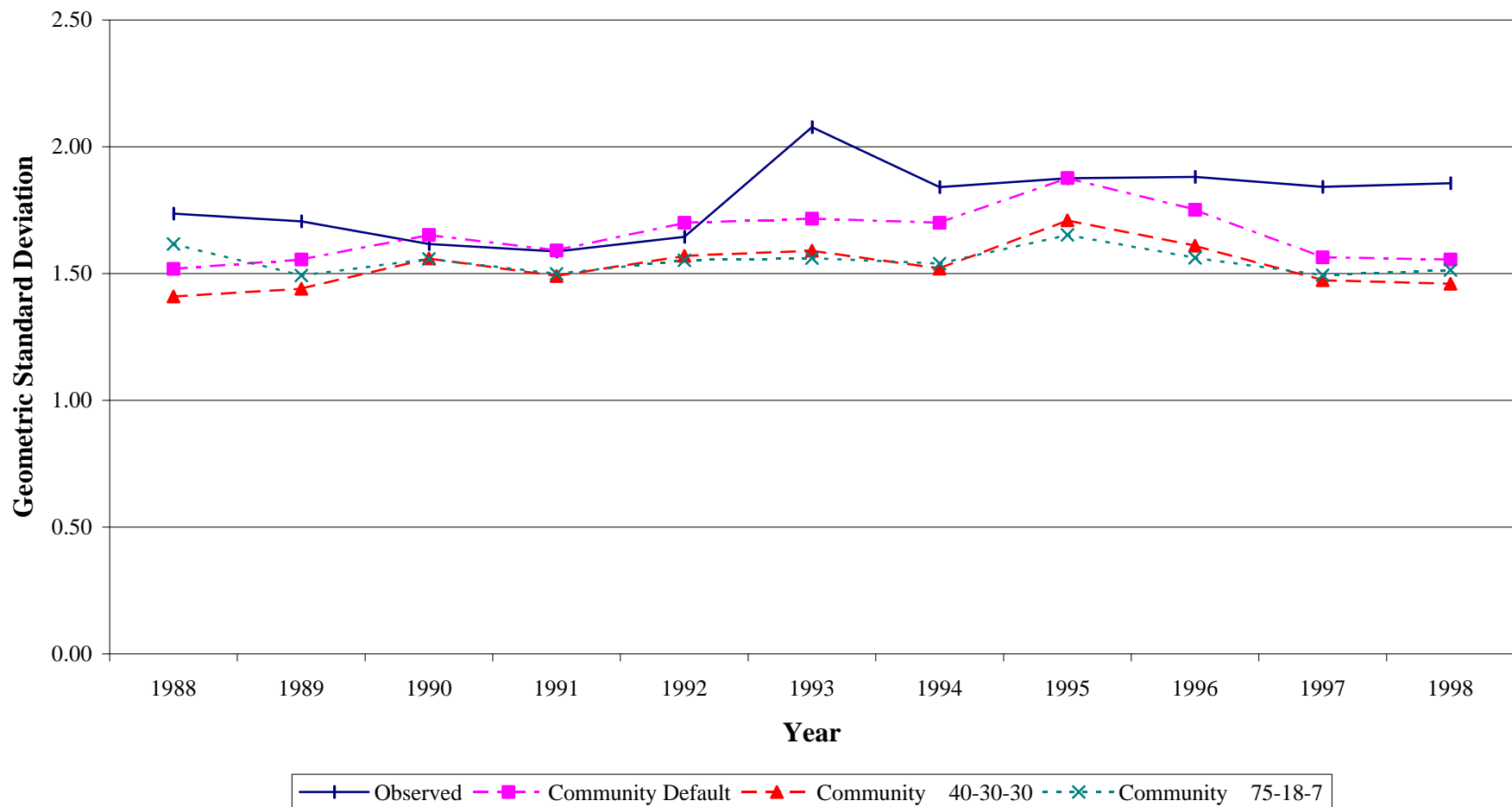


Figure Q4-13d
Predicted and Observed Geometric Standard Deviations Default Parameters
Three Dust: Soil Partition Scenarios
Kellogg 1988-1998

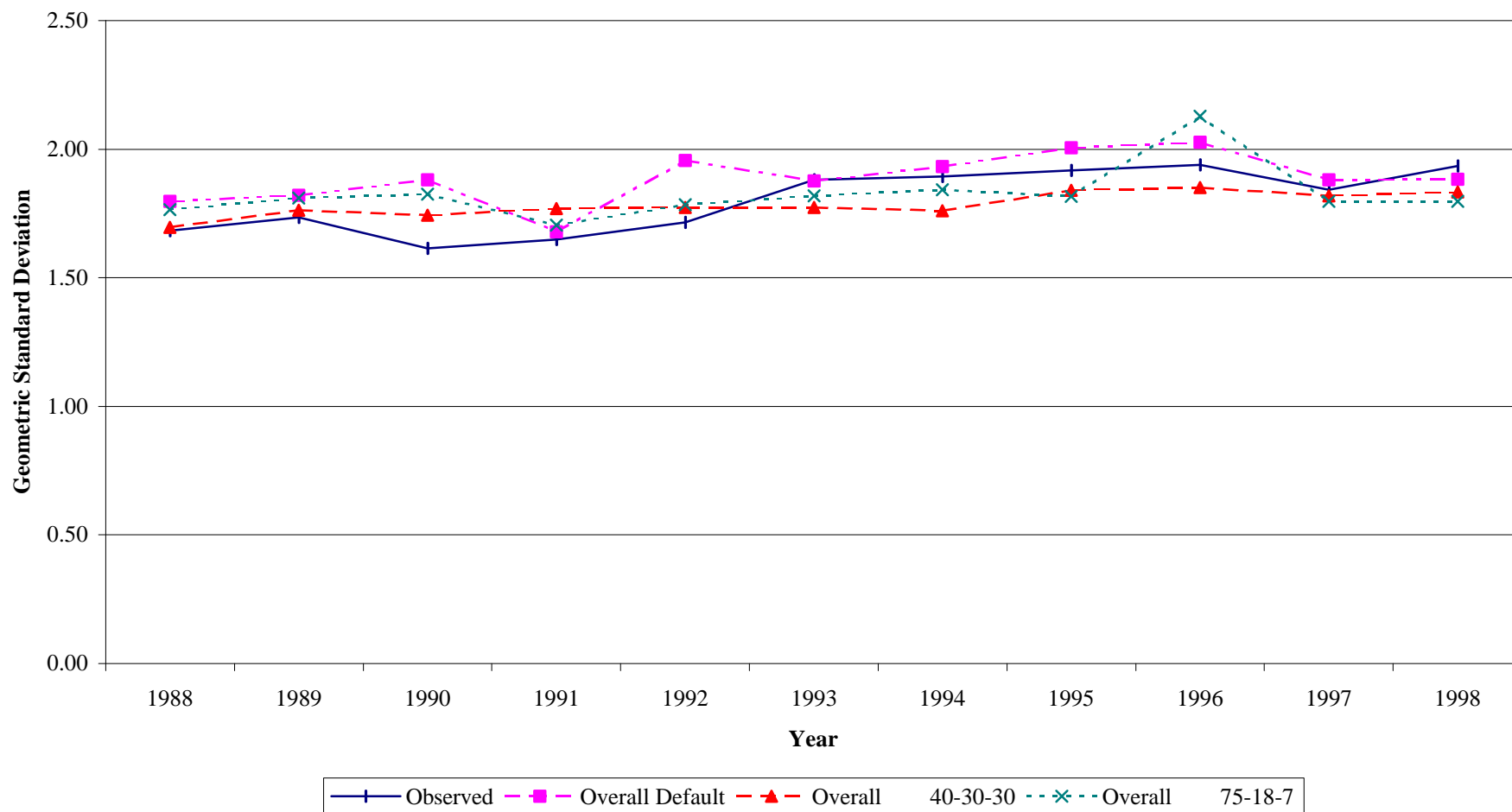


Figure Q4-13e
Predicted and Observed Geometric Standard Deviations Default Parameters
Three Dust: Soil Partition Scenarios
Smelterville 1988-1998

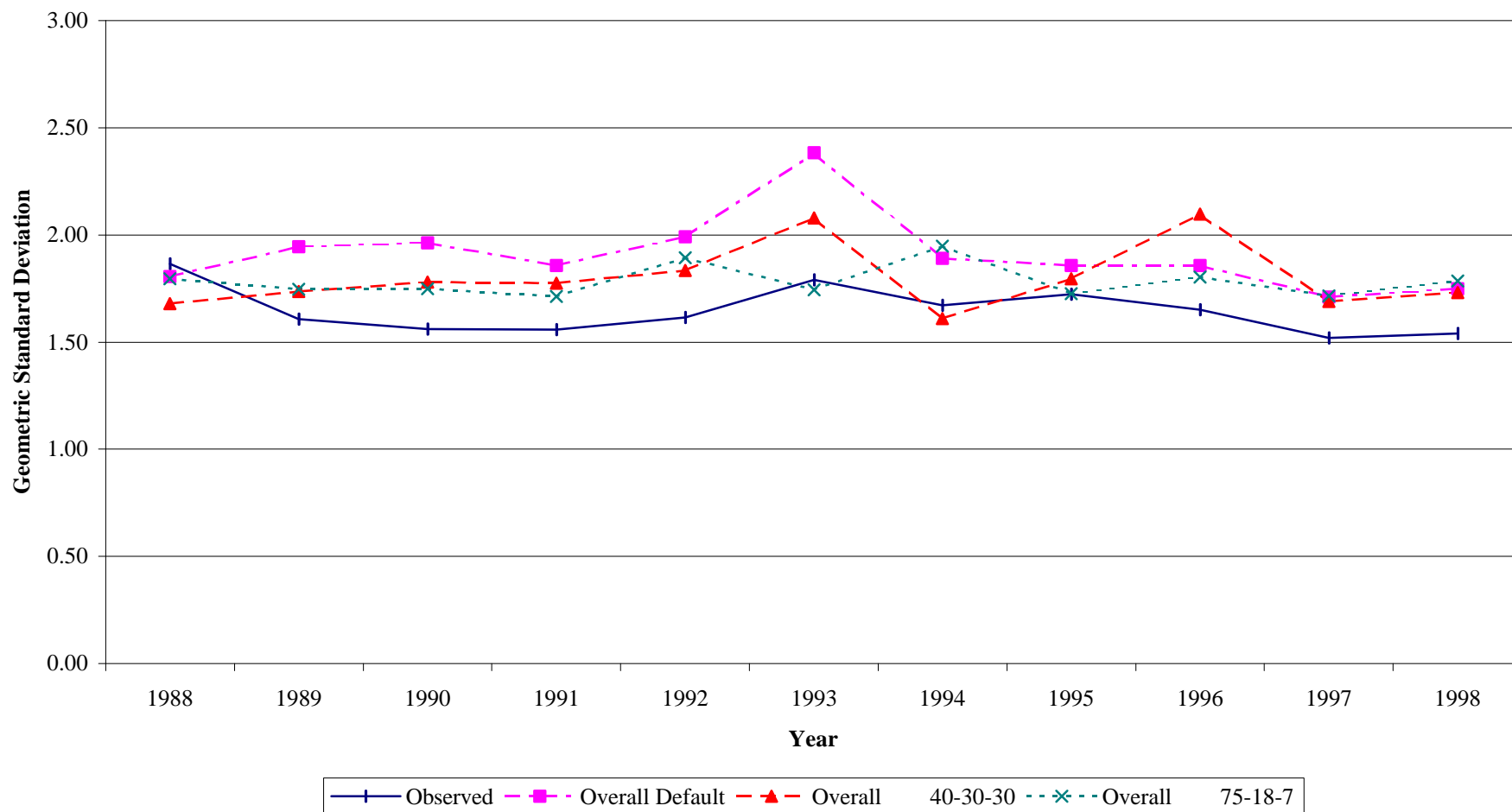
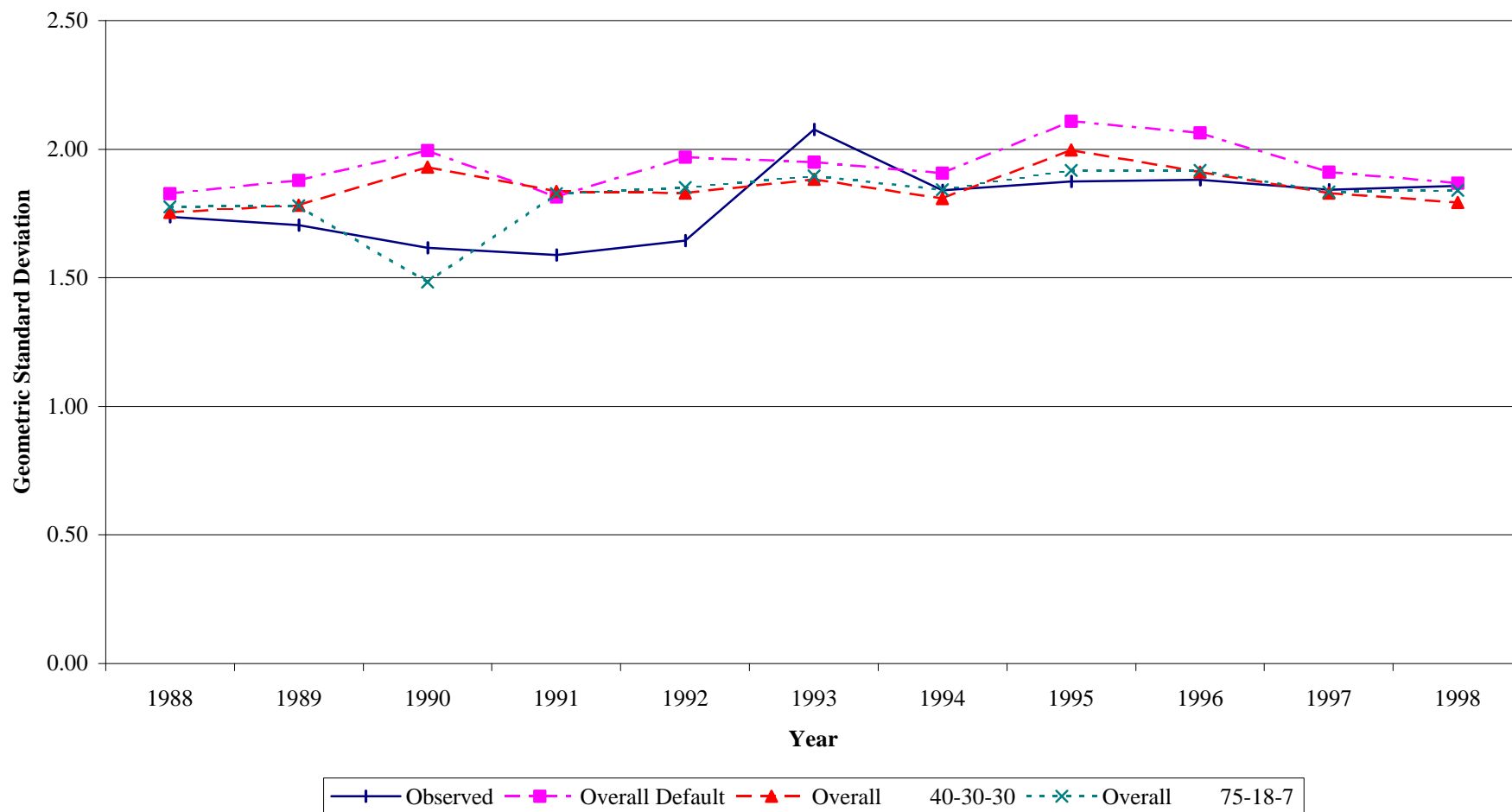


Figure Q4-13f
Predicted and Observed Geometric Standard Deviations Default Parameters
Three Dust: Soil Partition Scenarios
Site Wide 1988-1998



**Table Q4-26 Predicted and Observed Geometric Mean Blood Lead Levels for
0-9 Year Old Children, Default Parameters - Three Dust:Soil Partition Scenarios**

Observed and Predicted Blood Lead Levels (µg/dl)					
Year	GSD	Observed	Default	40-30-30	75-18-7
Kellogg					
1988	1.7	8.1	16.4	17.7	15.0
1989	1.8	9.3	16.2	16.8	15.2
1990	1.7	8.3	11.4	12.6	11.7
1991	1.8	6.0	9.3	10.0	10.4
1992	1.8	6.9	8.3	9.1	9.1
1993	1.8	5.2	7.2	7.9	8.1
1994	1.8	5.5	6.8	7.5	7.4
1995	1.8	5.2	8.1	8.3	8.1
1996	1.9	5.1	6.3	6.8	6.7
1997	1.8	4.9	5.7	5.9	6.5
1998	1.8	4.0	5.6	5.3	6.3
Smelterville					
1988	1.7	11.5	13.6	15.6	12.7
1989	1.7	13.2	13.3	15.6	12.8
1990	1.8	8.7	13.7	15.3	14.9
1991	1.8	5.9	10.1	11.7	11.5
1992	1.8	7.4	8.3	10.0	9.2
1993	2.1	5.8	10.2	11.2	11.0
1994	1.6	5.3	7.4	8.9	8.7
1995	1.8	6.2	6.3	6.3	7.1
1996	1.8	5.8	5.4	5.5	6.2
1997	1.7	5.2	3.7	3.4	3.9
1998	1.7	5.8	5.0	4.4	5.7
Site Wide					
1988	1.8	8.5	14.7	16.1	13.1
1989	1.8	9.9	14.6	15.5	13.7
1990	1.9	7.9	9.8	10.4	10.2
1991	1.8	5.5	8.2	8.8	9.1
1992	1.8	6.5	7.6	8.2	8.3
1993	1.9	4.4	7.0	7.4	7.7
1994	1.8	5.1	6.3	6.9	6.9
1995	2.0	5.0	6.8	6.8	6.8
1996	1.9	4.7	5.7	5.9	6.1
1997	1.8	4.5	5.3	5.3	5.7
1998	1.8	4.0	5.2	5.0	5.7

**Table Q4-27 Predicted and Observed Geometric Standard
Deviation, 1988-1998, Default Parameters -
Three Dust:Soil Partition Scenarios**

Observed and Predicted Geometric Standard Deviations							
Year	Observed	Community Default	Overall Default	Community 40-30-30	Overall 40-30-30	Community 75-18-7	Overall 75-18-7
Kellogg							
1988	1.68	1.43	1.80	1.32	1.70	1.40	1.76
1989	1.74	1.48	1.82	1.38	1.76	1.45	1.81
1990	1.61	1.56	1.88	1.35	1.74	1.40	1.83
1991	1.65	1.55	1.68	1.40	1.77	1.38	1.71
1992	1.72	1.74	1.96	1.51	1.77	1.52	1.78
1993	1.88	1.70	1.88	1.50	1.77	1.50	1.82
1994	1.89	1.73	1.93	1.50	1.76	1.50	1.84
1995	1.92	1.88	2.01	1.63	1.84	1.57	1.82
1996	1.94	1.79	2.03	1.57	1.85	1.82	2.13
1997	1.84	1.58	1.88	1.45	1.82	1.47	1.80
1998	1.93	1.59	1.88	1.48	1.83	1.48	1.80
Smelterville							
1988	1.87	1.44	1.80	1.25	1.68	1.41	1.79
1989	1.61	1.60	1.95	1.36	1.74	1.39	1.75
1990	1.56	1.54	1.96	1.37	1.78	1.38	1.75
1991	1.56	1.51	1.86	1.34	1.78	1.31	1.71
1992	1.61	1.80	1.99	1.50	1.83	1.55	1.89
1993	1.79	1.76	2.38	1.51	2.08	1.46	1.74
1994	1.67	1.89	1.89	1.55	1.61	1.62	1.95
1995	1.72	1.83	1.86	1.67	1.80	1.61	1.72
1996	1.65	1.69	1.86	1.63	2.10	1.70	1.80
1997	1.52	1.25	1.71	1.23	1.69	1.25	1.72
1998	1.54	1.37	1.75	1.34	1.73	1.37	1.78
Site Wide							
1988	1.74	1.52	1.83	1.41	1.75	1.62	1.78
1989	1.71	1.56	1.88	1.44	1.78	1.49	1.78
1990	1.62	1.65	1.99	1.56	1.93	1.56	1.48
1991	1.59	1.59	1.81	1.49	1.84	1.50	1.83
1992	1.65	1.70	1.97	1.57	1.83	1.55	1.85
1993	2.08	1.72	1.95	1.59	1.88	1.56	1.90
1994	1.84	1.70	1.91	1.52	1.81	1.54	1.84
1995	1.88	1.88	2.11	1.71	2.00	1.65	1.92
1996	1.88	1.75	2.06	1.61	1.91	1.56	1.92
1997	1.84	1.56	1.91	1.47	1.83	1.49	1.83
1998	1.86	1.56	1.87	1.46	1.79	1.51	1.84

Figure Q4-14a
Predicted and Observed Percent of Children with Blood Lead Level Exceeding 10 $\mu\text{g}/\text{dl}$
Default Parameters - Three Dust : Soil Partition Scenarios
Kellogg 1988-1998

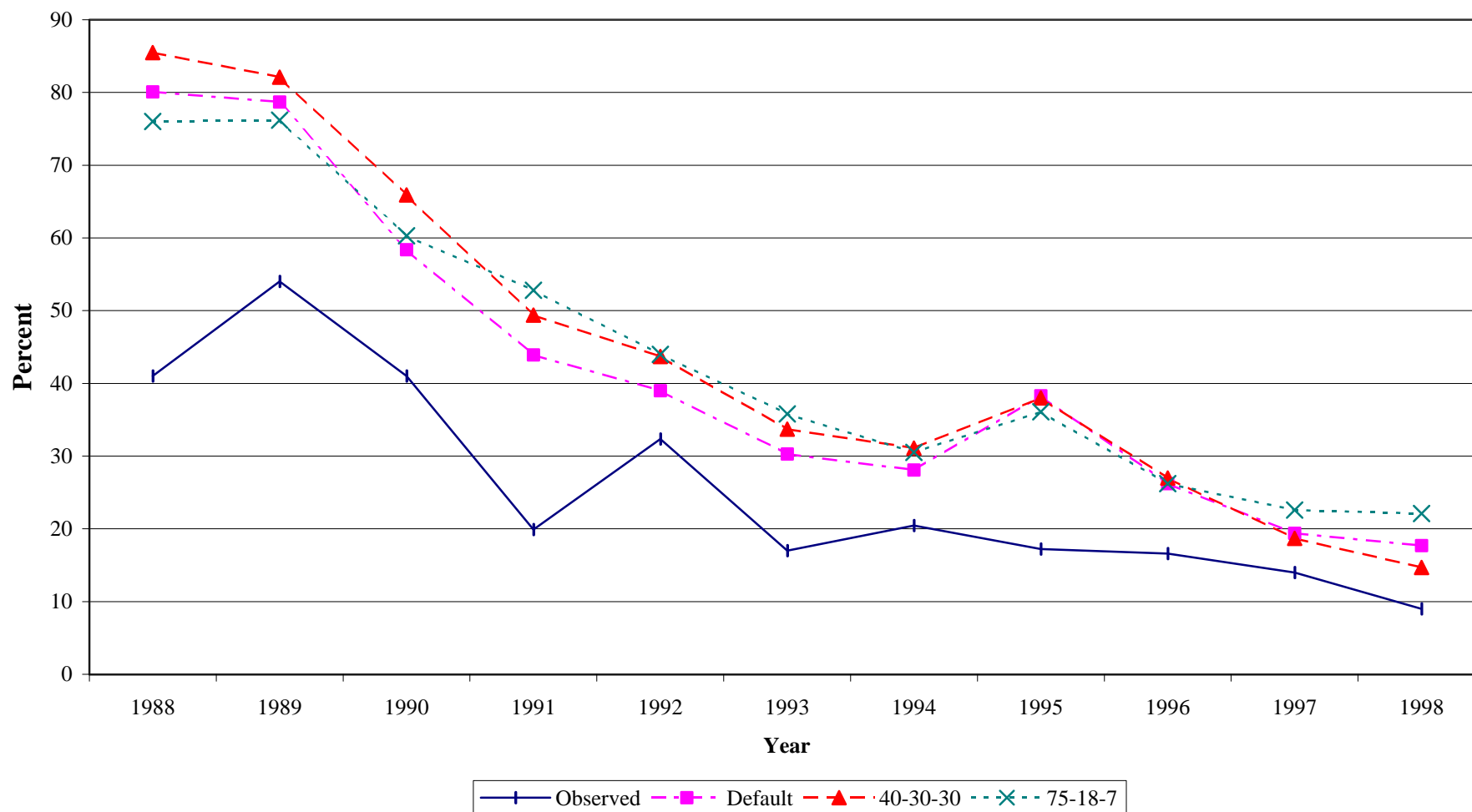


Figure Q4-14b
Predicted and Observed Percent of Children with Blood Lead Level Exceeding 10 μ g/dl
Default Parameters - Three Dust : Soil Partition Scenarios
Smelterville 1988-1998

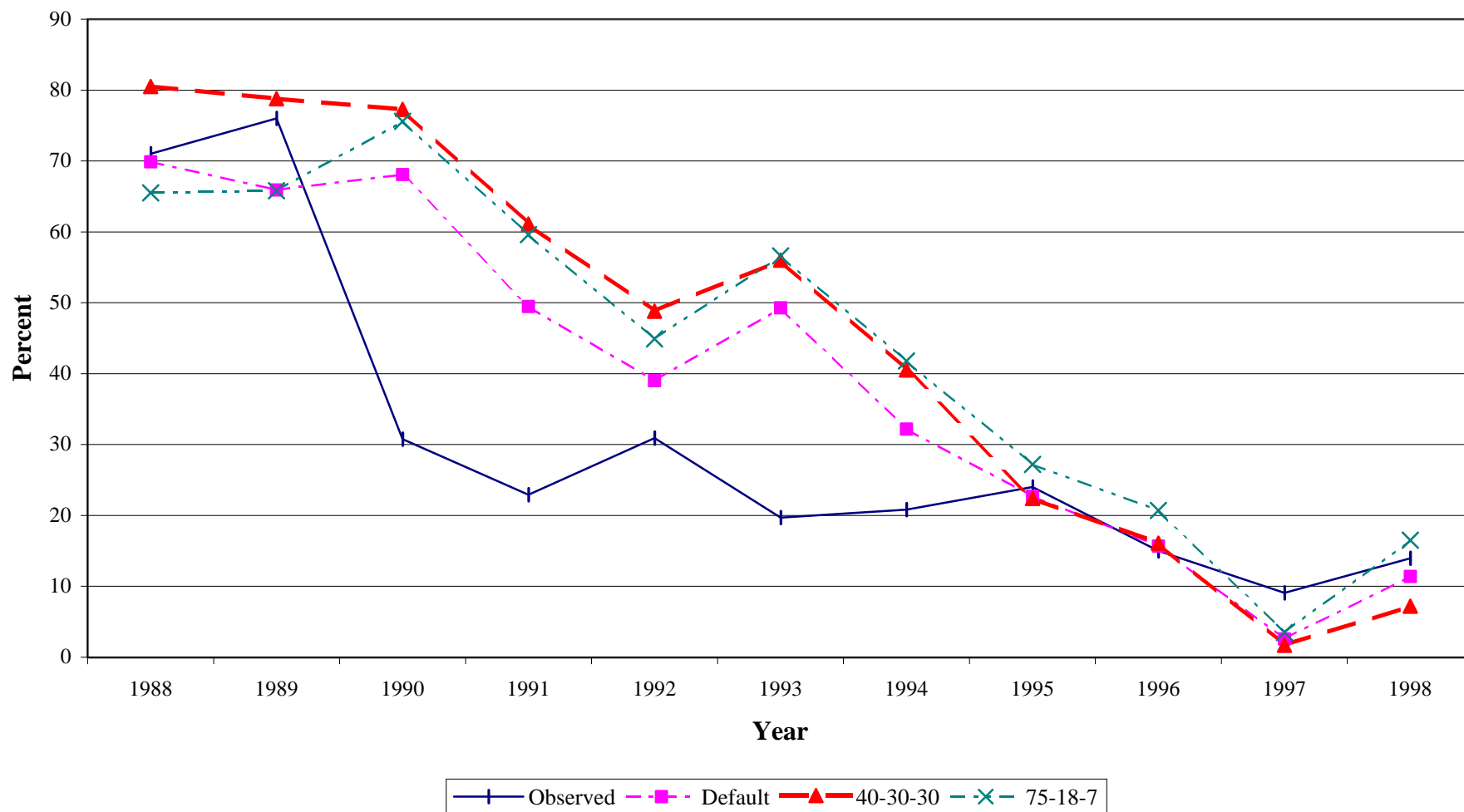


Figure Q4-14c
Predicted and Observed Percent of Children with Blood Lead Level Exceeding 10 µg/dl
Default Parameters - Three Dust : Soil Partition Scenarios
Sitewide 1988-1998

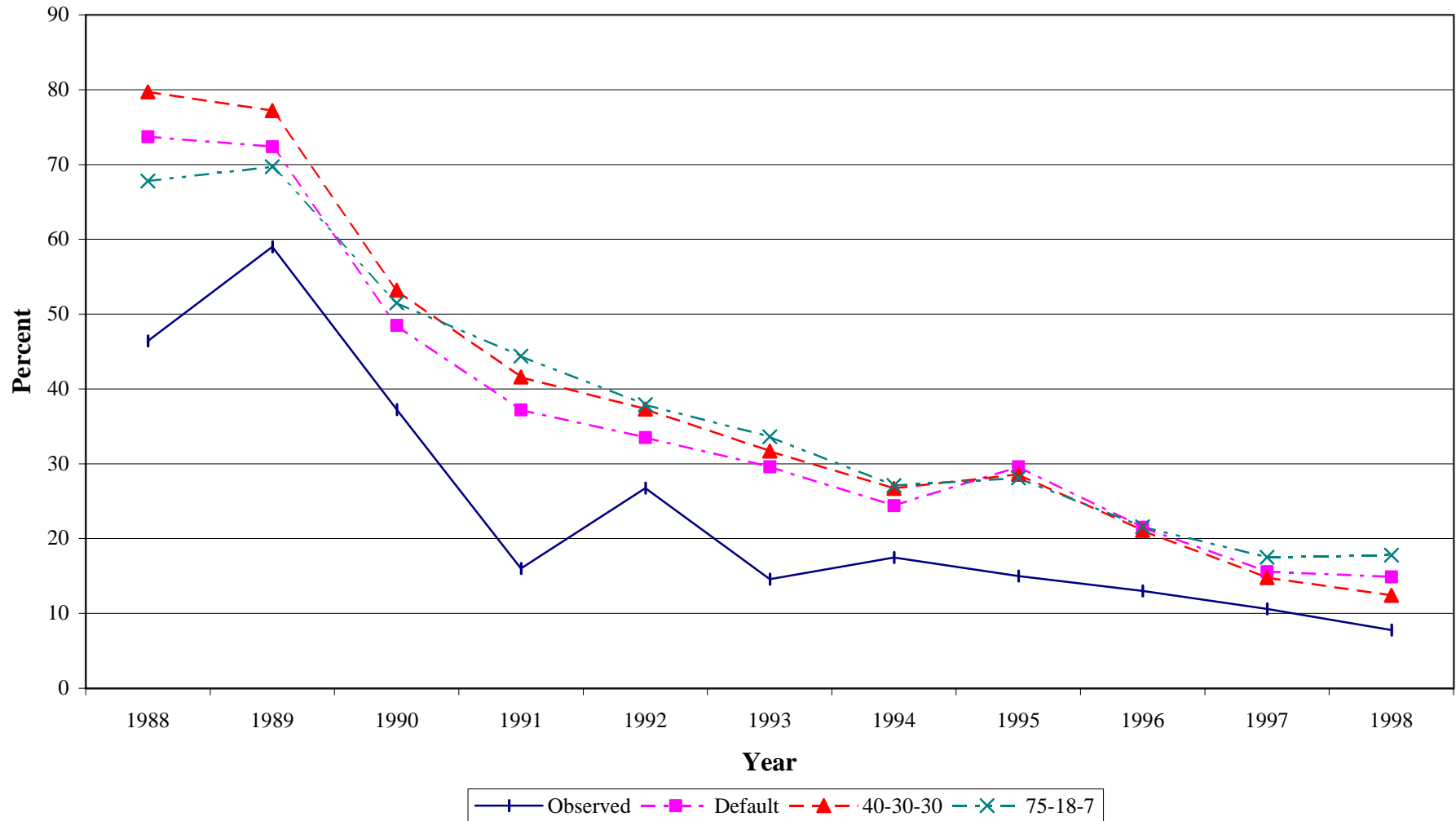


Table Q4-28 Predicted and Observed Lead Toxicity
Percent of Children With Blood Lead Greater Than 10 µg/dl
Default Parameters - Three Dust:Soil Partition Scenarios

Observed and Predicted Lead Toxicity				
Year	Observed	Default	40-30-30	75-18-7
Kellogg				
1988	41	80	86	76
1989	54 (52) ¹	79	82	76
1990	41 (40)	58	66	60
1991	20	44	49	53
1992	32	39	44	44
1993	17 (18)	30	34	36
1994	20	28	31	31
1995	17	38	38	36
1996	17	26	27	26
1997	14 (15)	19	19	23
1998	9 (10)	18	15	22
Smelterville				
1988	71 (72)	70	81	66
1989	76 (78)	66	79	66
1990	31	68	77	76
1991	23	50	61	60
1992	31	39	49	45
1993	20	49	56	57
1994	21	32	41	42
1995	24 (28)	23	22	27
1996	15 (12)	16	16	21
1997	9	3	2	4
1998	14	11	7	17
Site Wide				
1988	46	74	80	68
1989	59 (56)	72	77	70
1990	37	49	53	52
1991	16 (15)	37	42	44
1992	27	34	37	38
1993	15	30	32	34
1994	17	24	27	27
1995	15	30	29	28
1996	13 (12)	22	21	22
1997	11	16	15	18
1998	8	15	12	18

Notes:

1 - Values in parentheses indicate total population values, and the full number of observations were not included in the model runs due to missing environmental media concentrations.

Figure Q4-15a
Predicted and Observed Blood Lead in Two Year Old Children
42:27:19:12 Dust:Soil Partition Scenarios at 18% Bioavailability
Kellogg 1988-1998

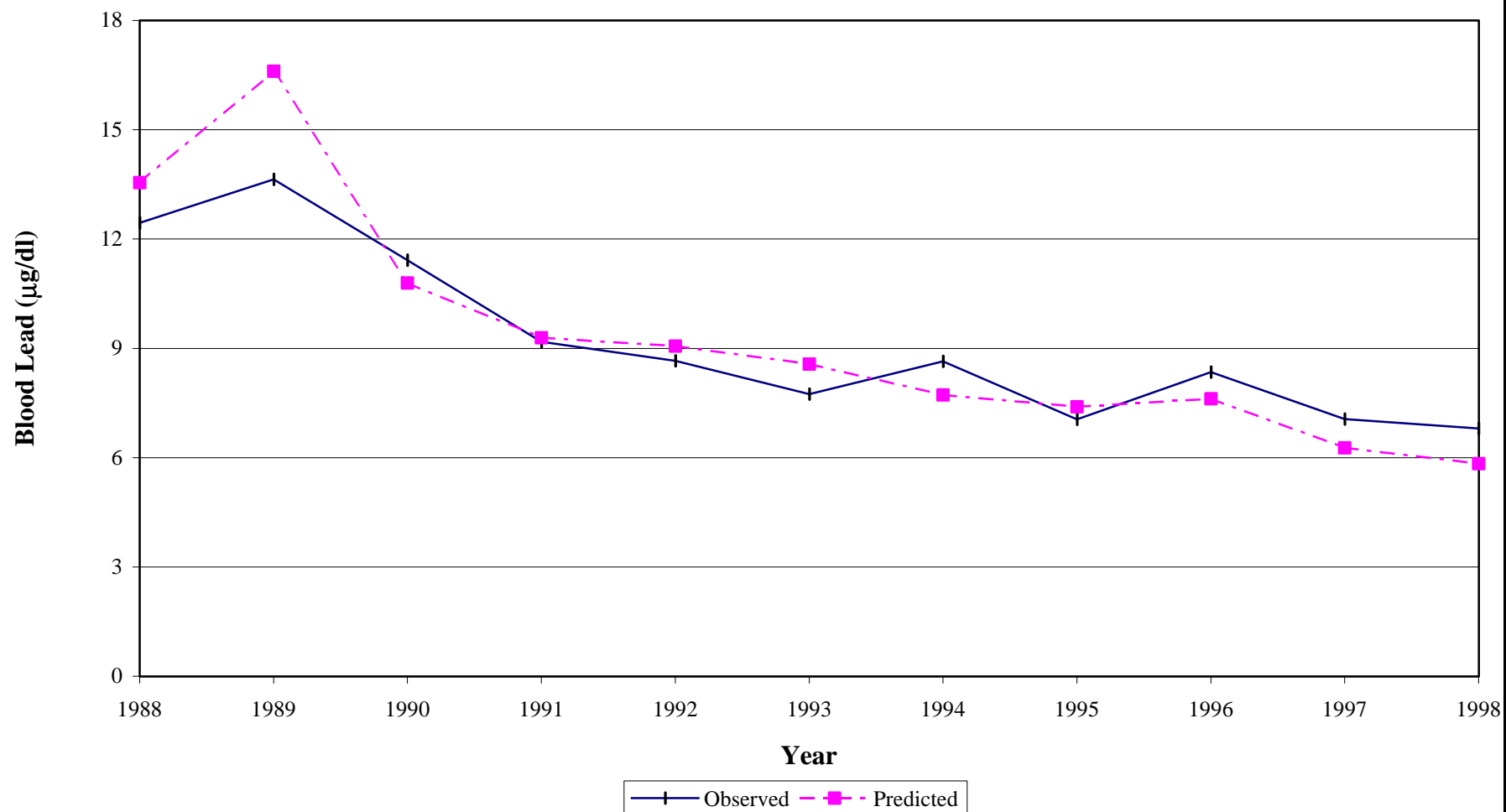


Figure Q4-15b
Predicted and Observed Blood Lead in Two Year Old Children
42:27:19:12 Dust:Soil Partition Scenarios at 18% Bioavailability
Smelterville 1988-1998

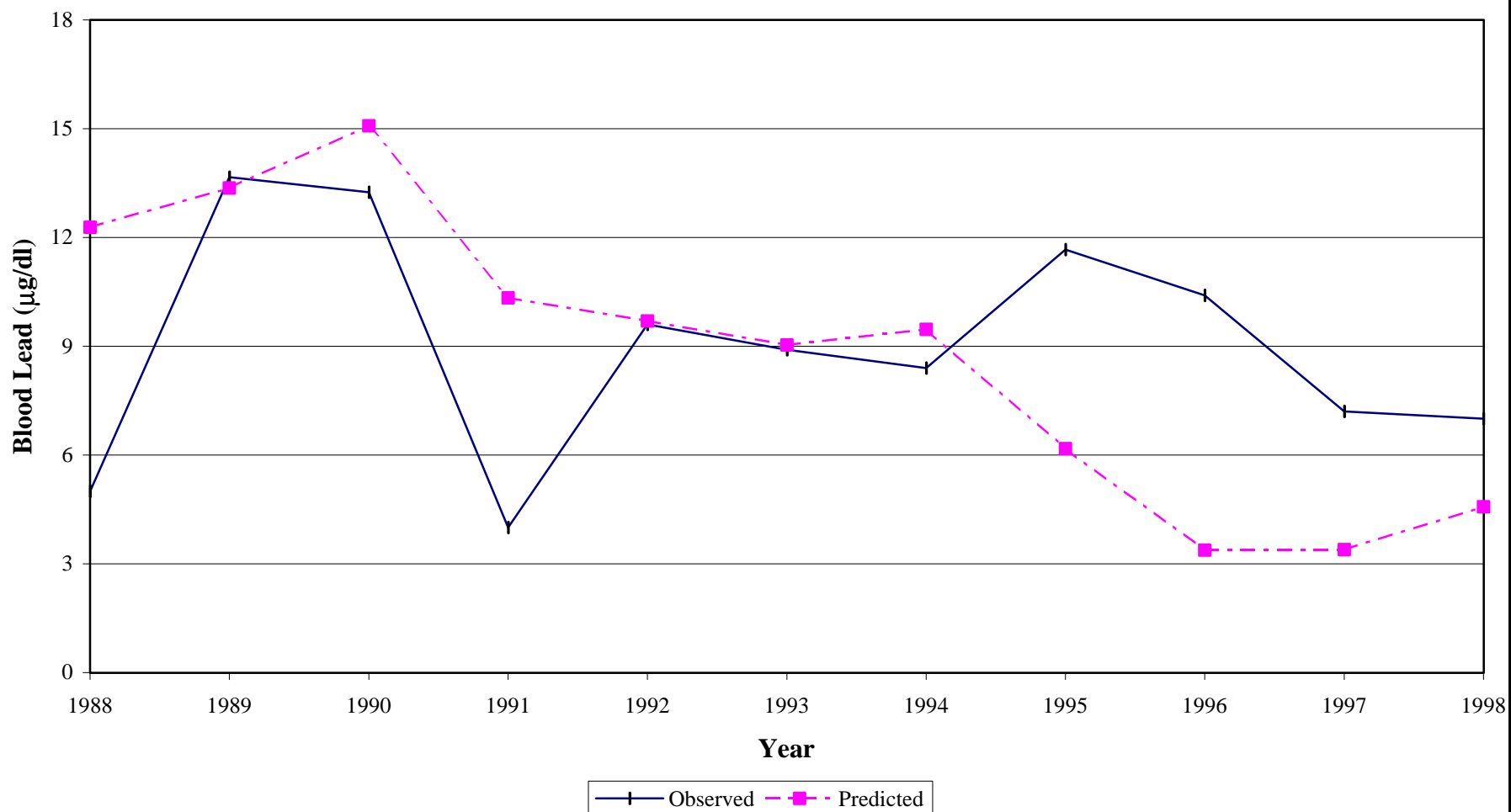


Figure Q4-15c
Predicted and Observed Blood Lead in Two Year Old Children
42:27:19:12 Dust:Soil Partition Scenarios at 18% Bioavailability
Site Wide 1988-1998

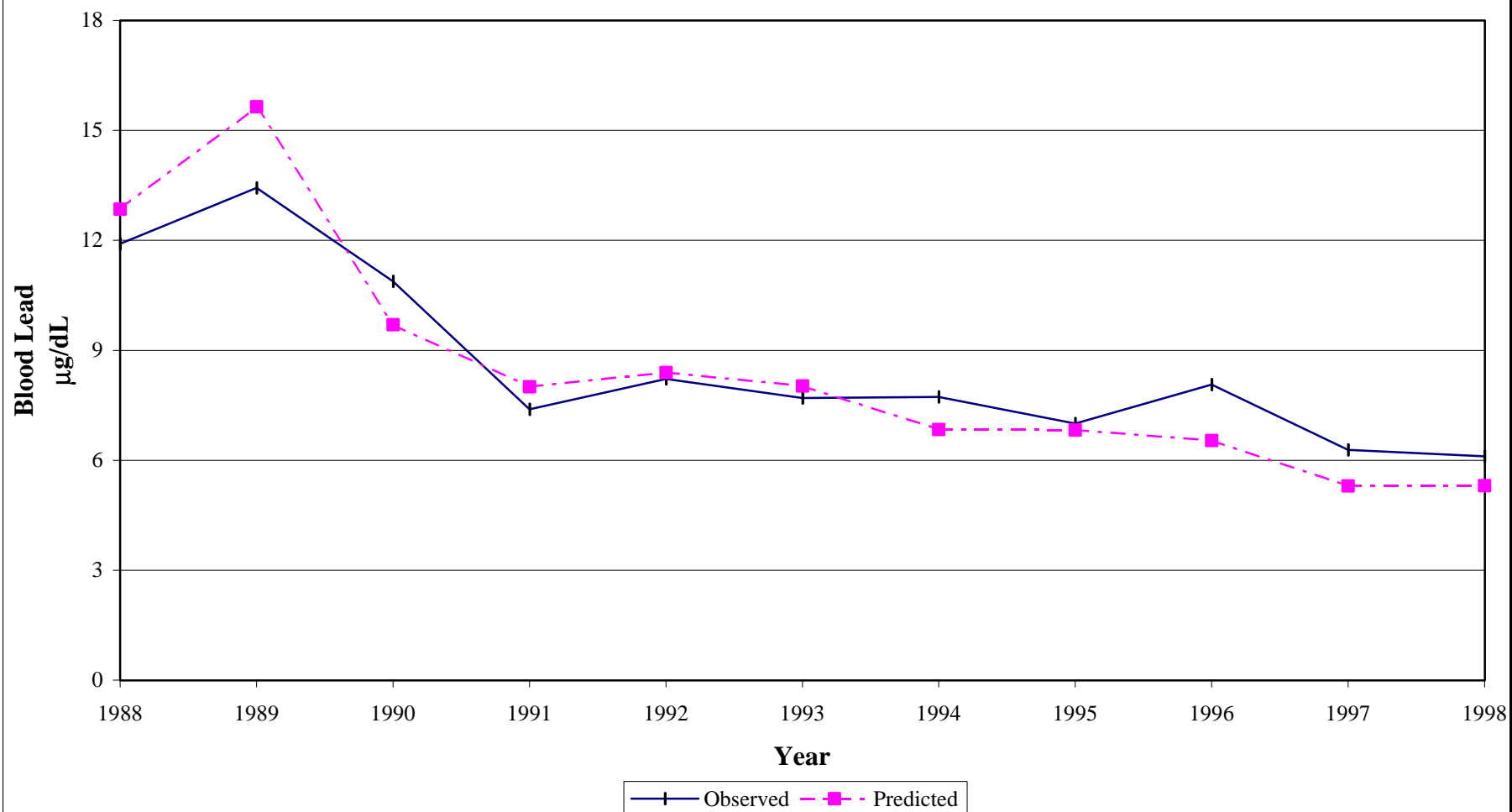


Figure Q4-16a
Predicted and Observed Geometric Standard Deviation
42:27:19:12 Dust:Soil Partition Scenarios at 18% Bioavailability
Kellogg 1988-1998

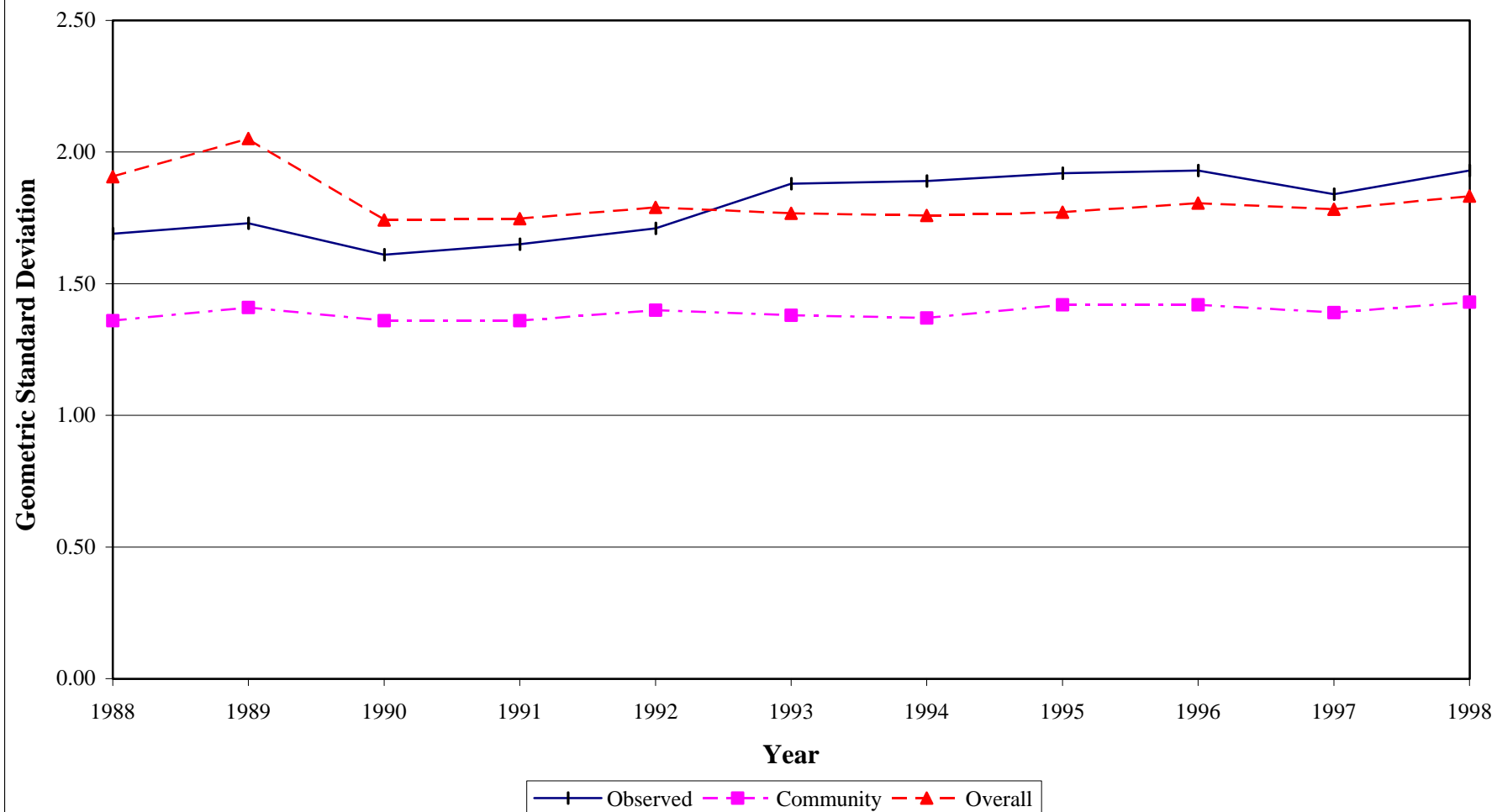


Figure Q4-16b
Predicted and Observed Geometric Standard Deviation
42:27:19:12 Dust:Soil Partition Scenarios at 18% Bioavailability
Smelterville 1988-1998

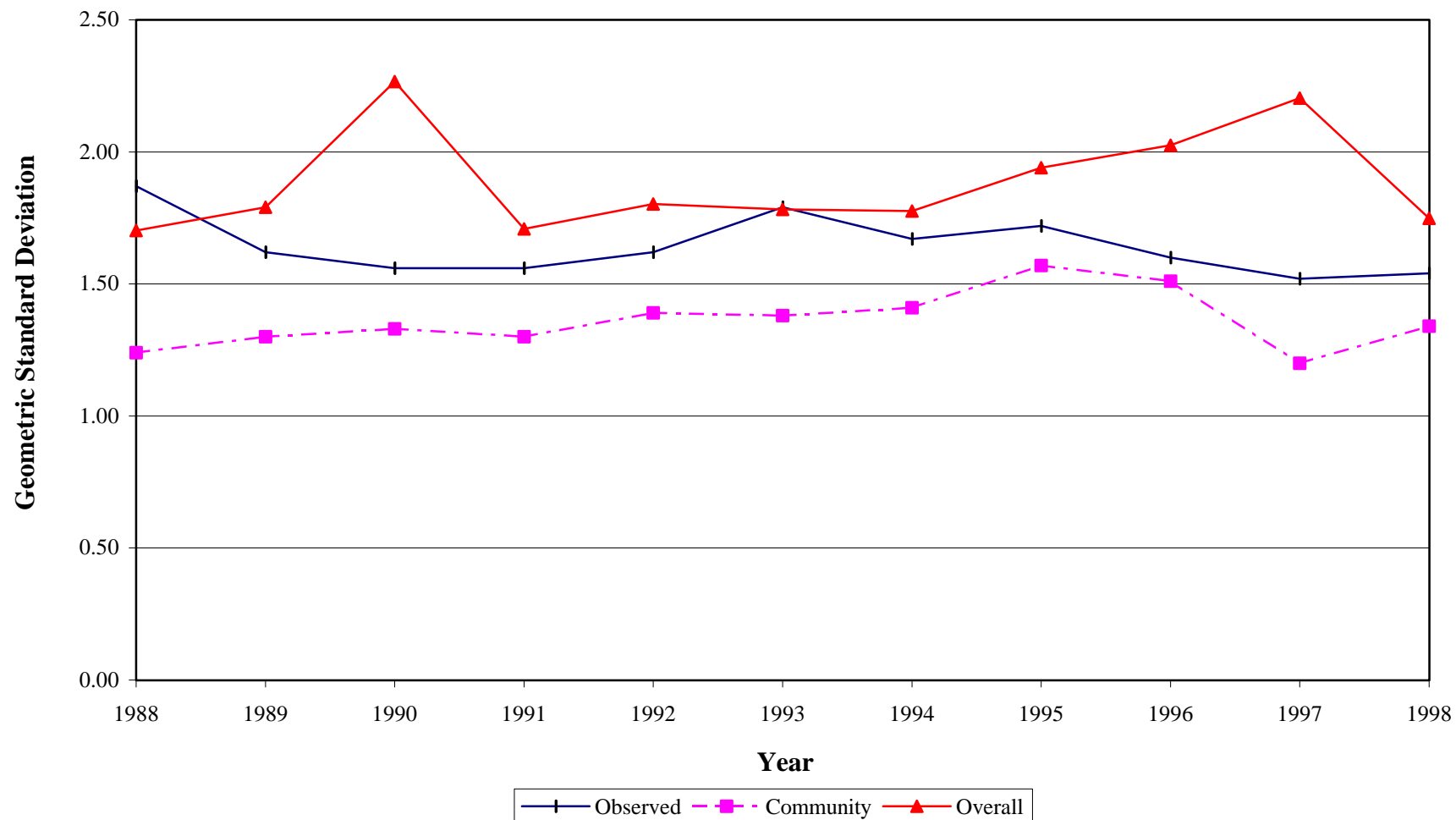


Figure Q4-16c
Predicted and Observed Geometric Standard Deviation
42:27:19:12 Dust:Soil Partition Scenarios at 18% Bioavailability
Site Wide 1988-1998

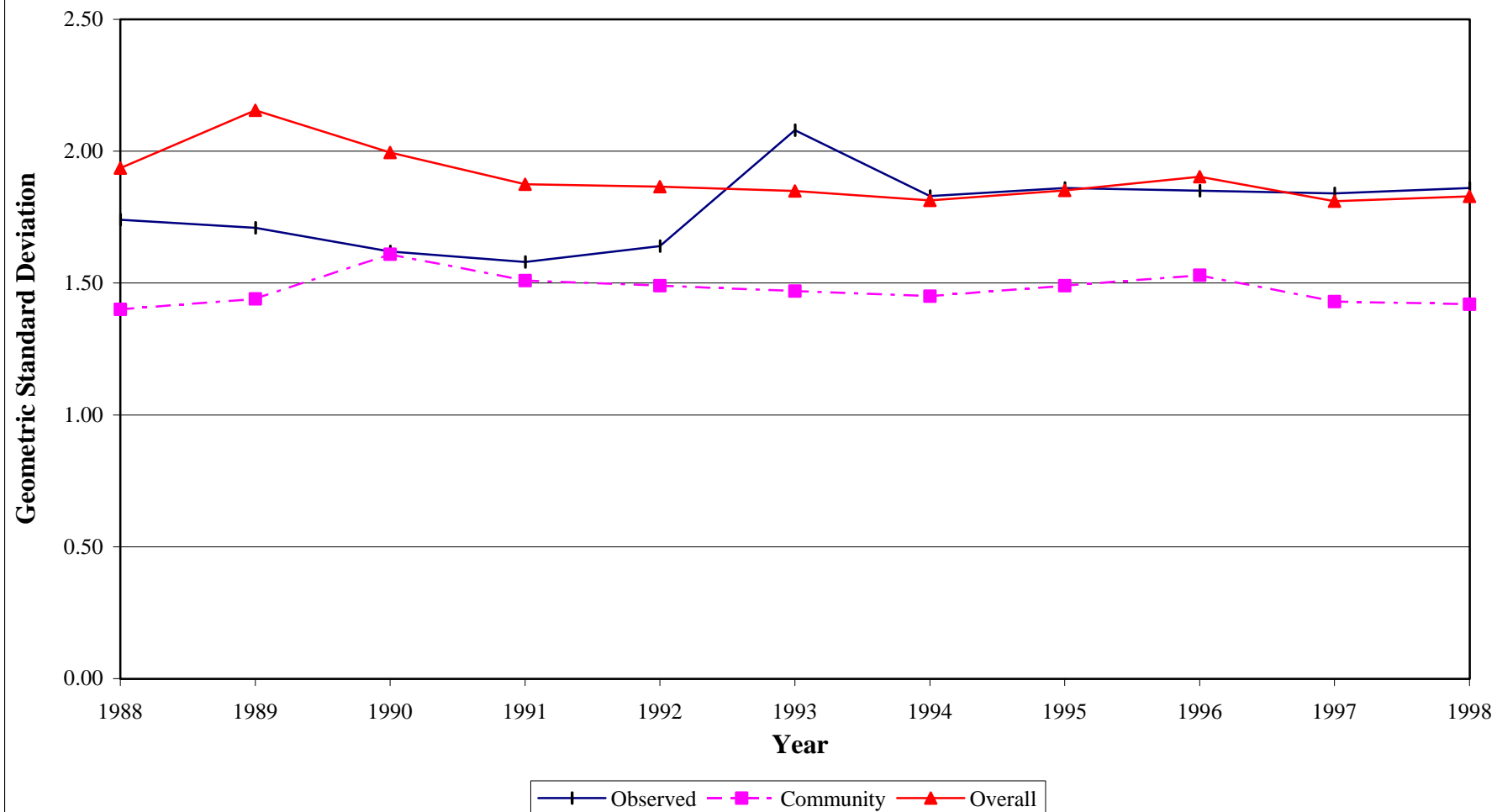


Figure Q4-17a
Predicted and Observed Percent of Children with Blood Lead Level Exceeding 10 $\mu\text{g}/\text{dl}$
42:27:19:12 Dust:Soil Partition Scenarios at 18% Bioavailability
Kellogg 1988-1998

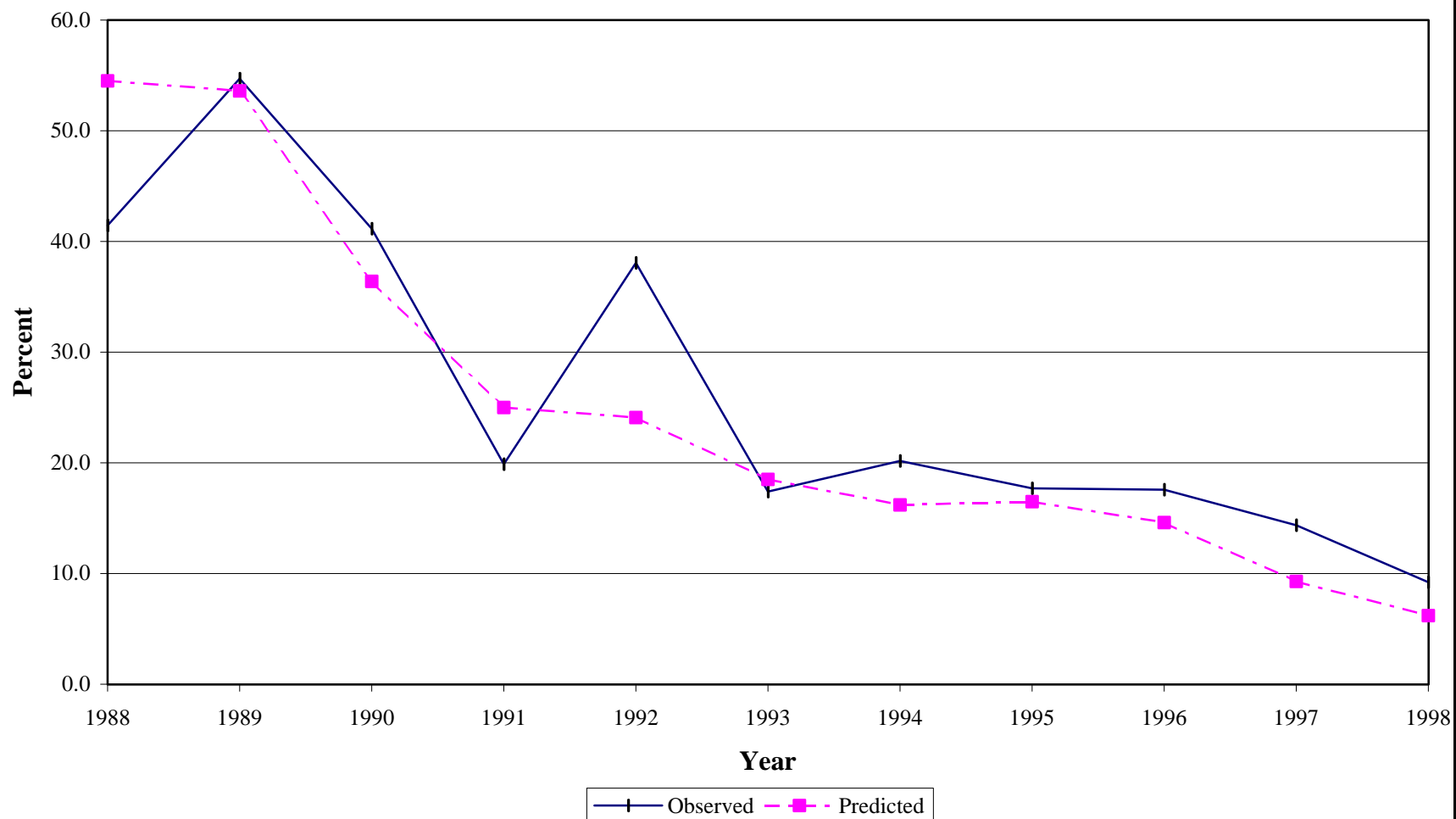


Figure Q4-17b
Predicted and Observed Percent of Children with Blood Lead Level Exceeding 10 µg/dl,
42:27:19:12 Dust:Soil Partition Scenarios at 18% Bioavailability
Smelterville 1988-1998

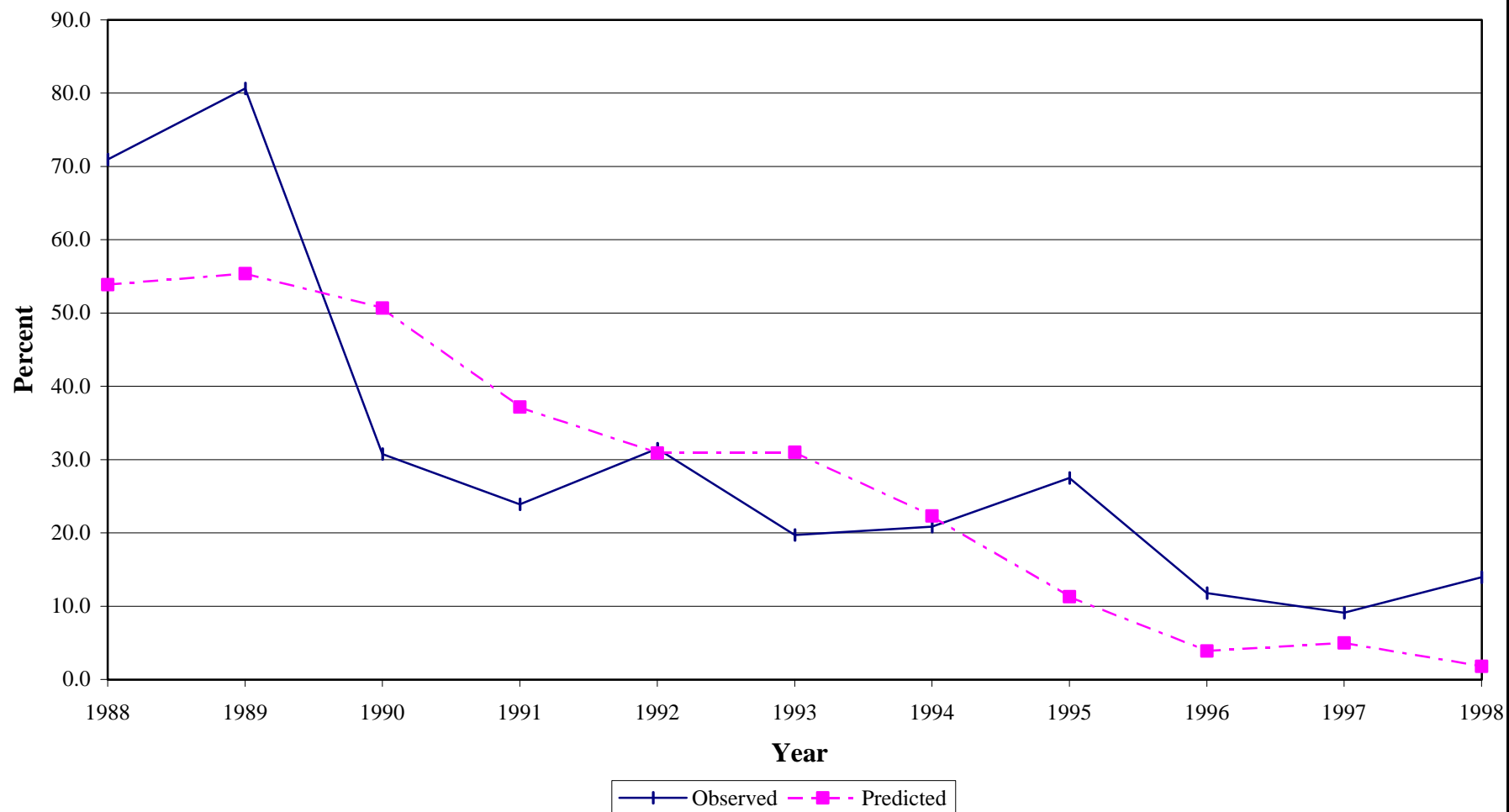


Figure Q4-17c
Predicted and Observed Percent of Children with Blood Lead Level Exceeding 10 µg/dl,
42:27:19:12 Dust:Soil Partition Scenarios at 18% Bioavailability
Site Wide 1988-1998

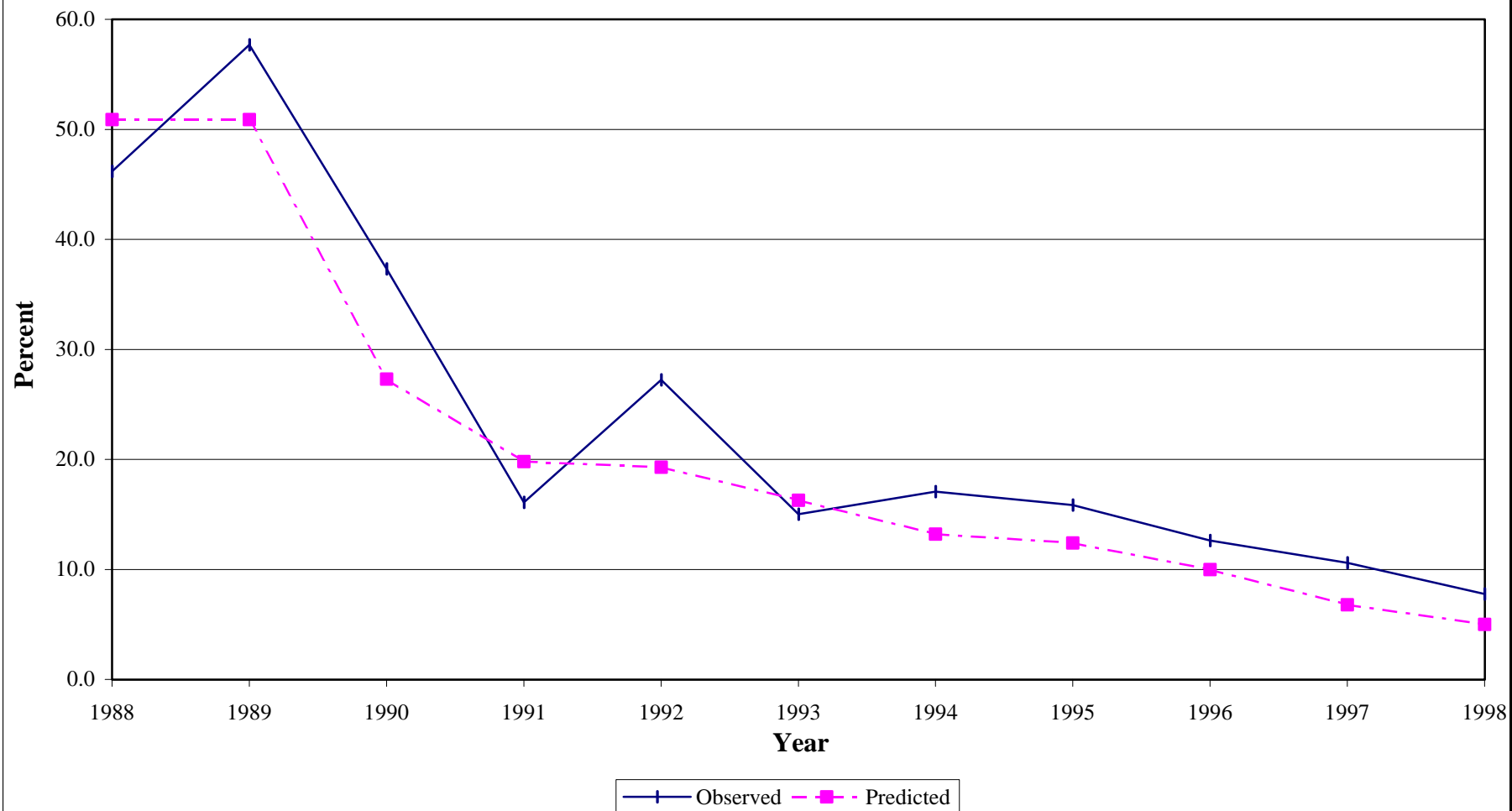


Figure Q4-18a
Observed vs. Predicted Arithmetic Mean Blood Lead Levels
Default Scenario at 30% Bioavailability
Site Wide 1988-1998

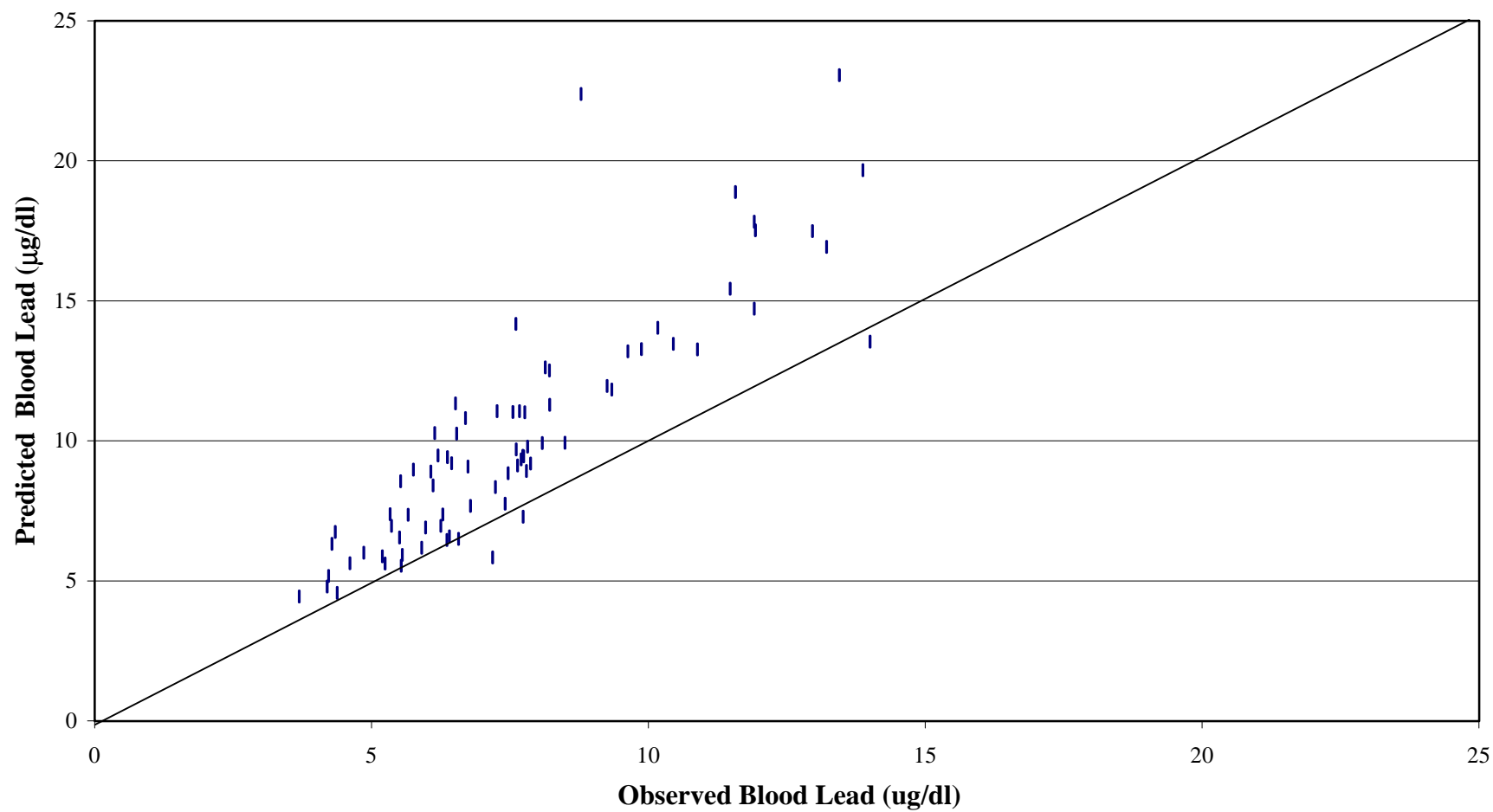


Figure Q4-18b
Observed vs Predicted Arithmetic Mean Blood Lead Levels
42:27:19:12 Dust:Soil Partition Scenario at 18% Bioavailability
Site Wide 1988-1998

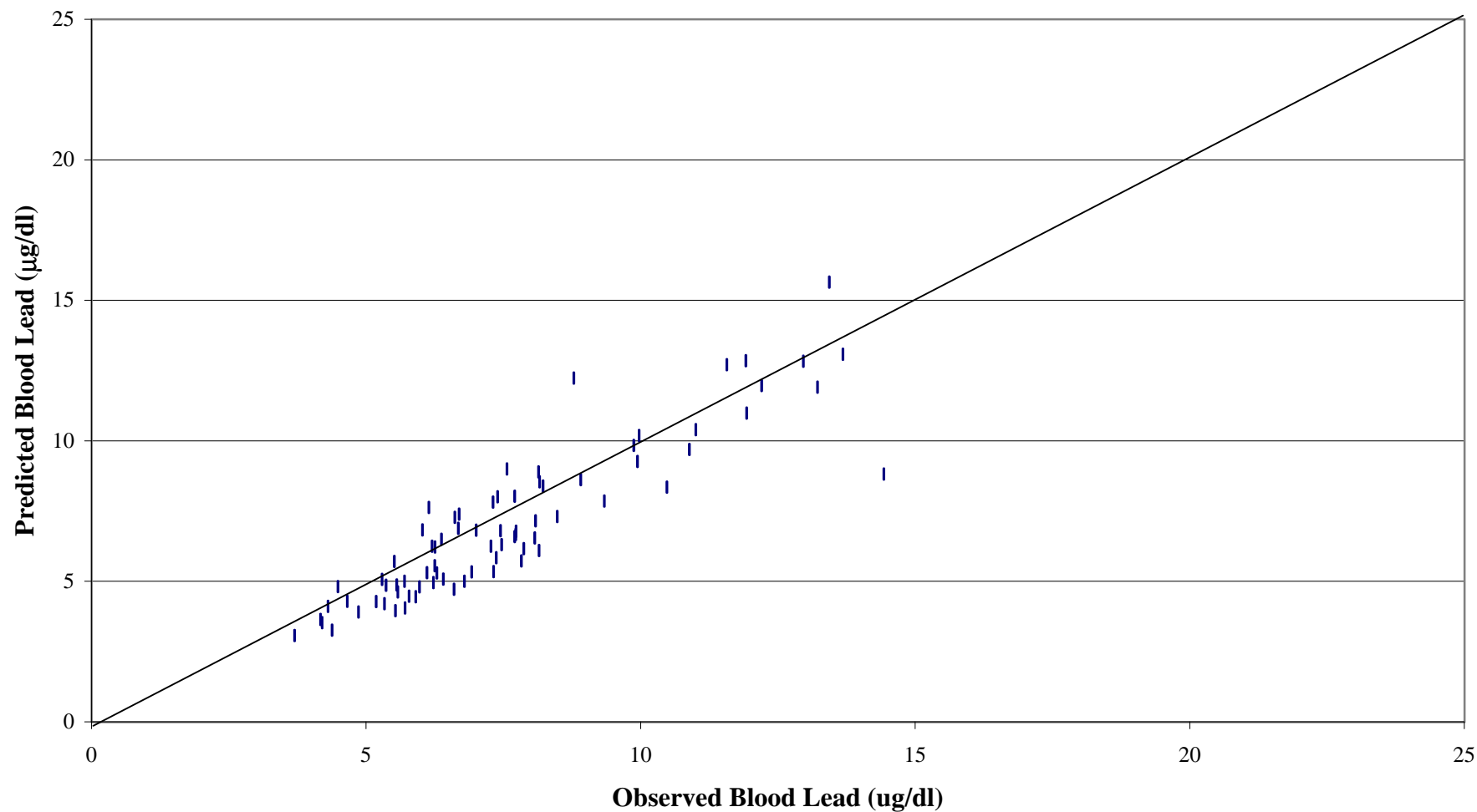


Figure Q4-19a
Observed vs. Predicted Geometric Mean Blood Lead Levels
Default Scenario at 30% Bioavailability
Site Wide 1988-1998

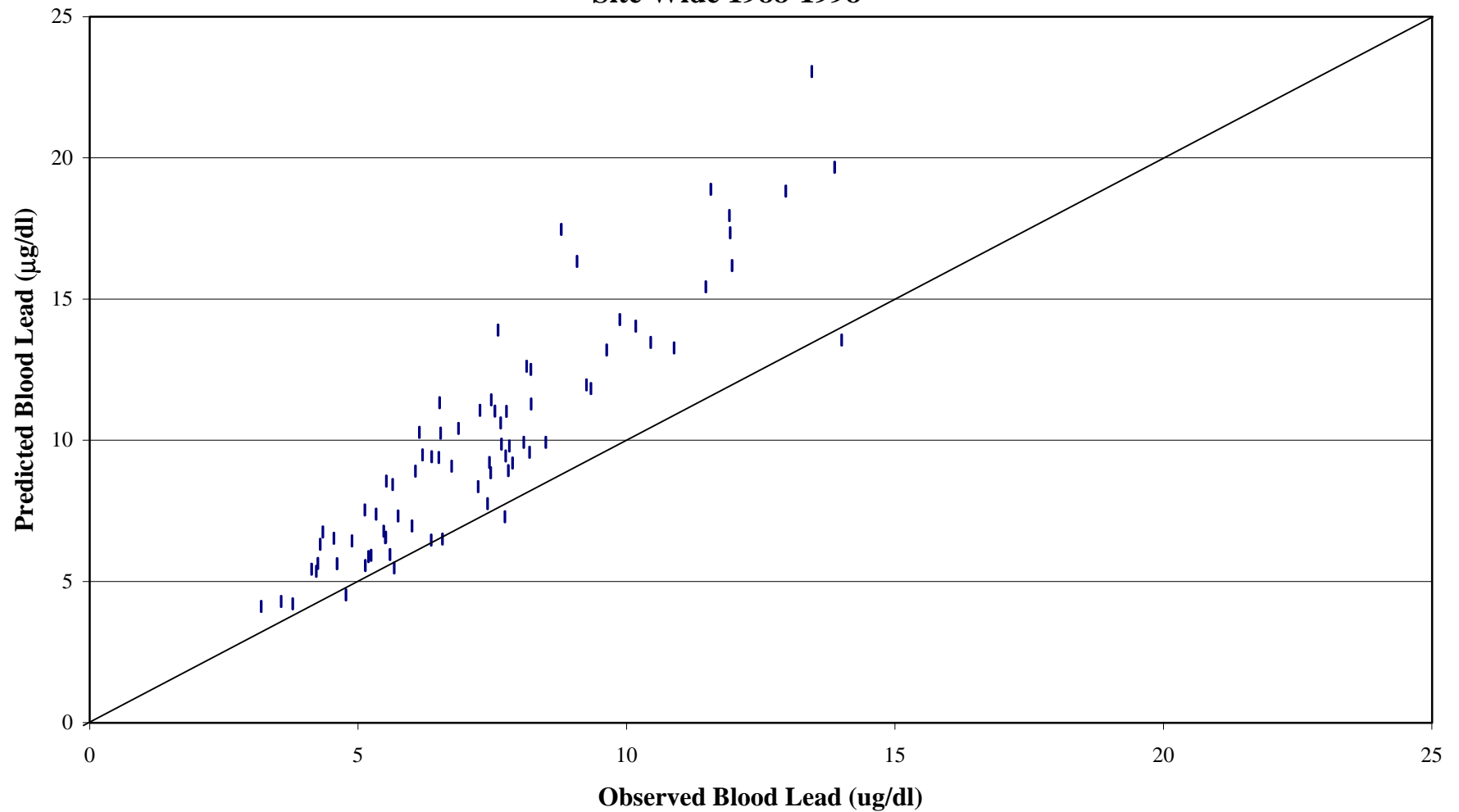


Figure Q4-19b
Observed vs. Predicted Geometric Mean Blood Lead Levels
42:27:19:12 Dust:Soil Partition Scenario at 18% Bioavailability
Site Wide 1988-1998

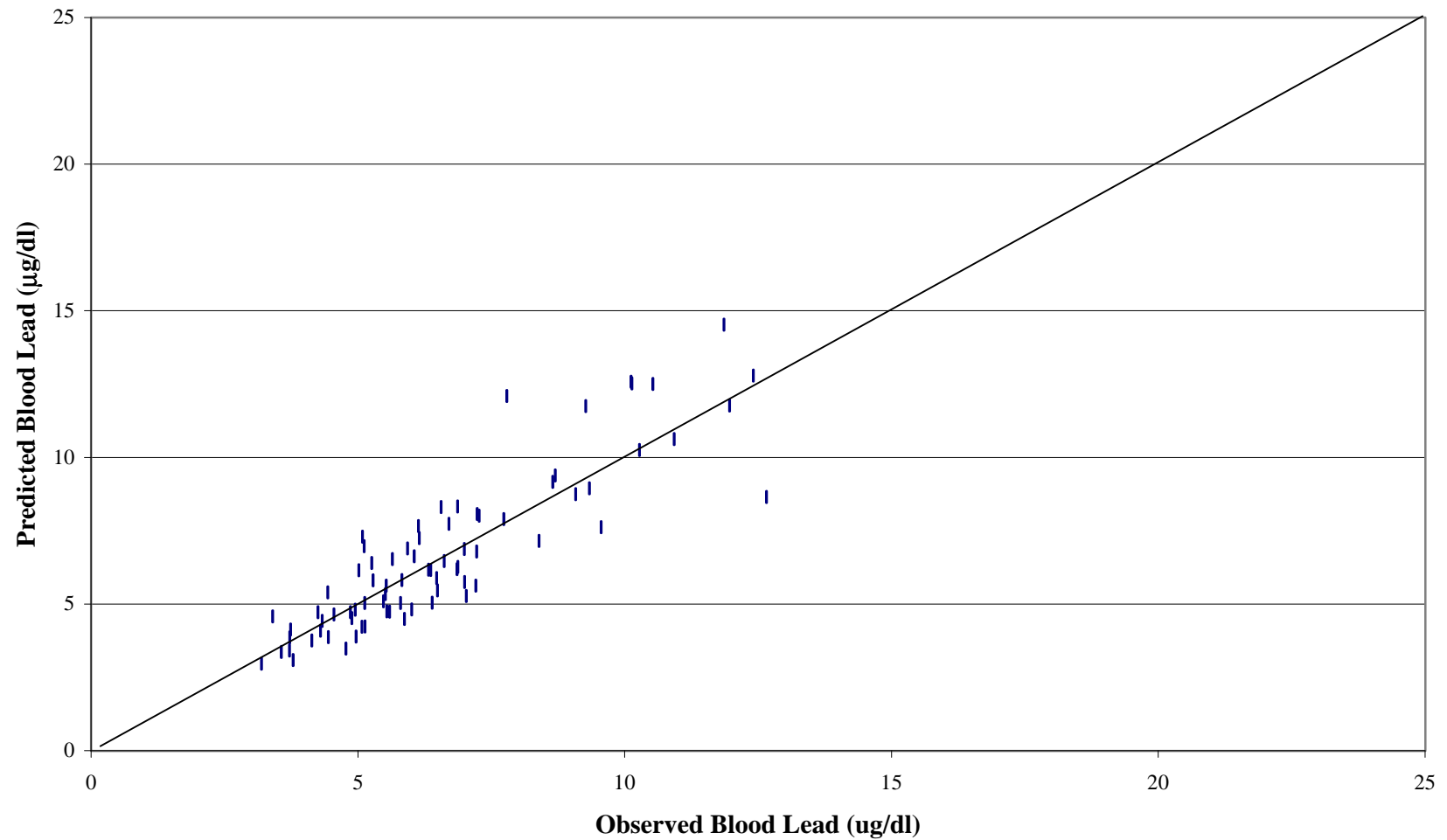


Figure Q4-20
Estimated Bioavailability Trends, 1988-1998

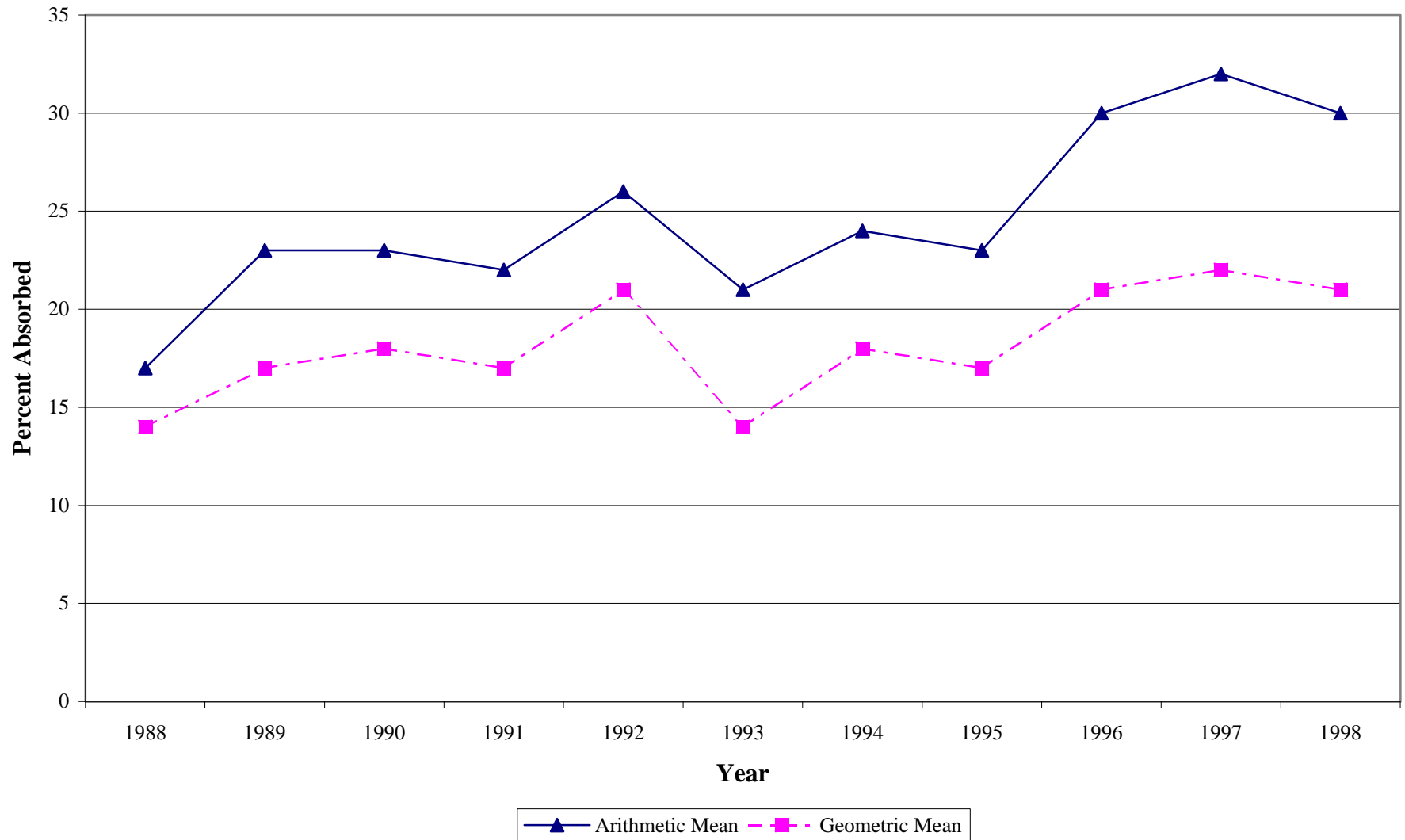


Table Q4-29
Estimated Aggregate Soil and Dust Effective Bioavailability 1988-1998

Year	Bioavailability	
	Arithmetic Mean	Geometric Mean
1988	17	14
1989	23	17
1990	23	18
1991	22	17
1992	26	21
1993	21	14
1994	24	18
1995	23	17
1996	30	21
1997	32	22
1998	30	21

**Table Q4-30 Predicted and Observed Geometric Mean Blood Lead Levels,
Geometric Standard Deviations, and Toxicity for 0-9 Year Old Children
42:27:19:12 Dust:Soil Partition at 18% Bioavailability**

Year	Mean Blood Lead Levels 0-9 Year Old Children (µg/dl)		Geometric Standard Deviations		Percent of Children with Blood Lead \geq 10 µg/dl	
	Observed	Predicted	Observed	Overall	Observed	Predicted
Kellogg						
1988	8.1	10.8	1.69	1.91	41.4	54.5
1989	9.5	10.7	1.73	2.05	54.7	53.6
1990	8.3	8.2	1.61	1.74	41.1	36.4
1991	6.0	6.9	1.65	1.75	19.9	25.0
1992	7.0	6.6	1.71	1.79	38.1	24.1
1993	5.2	6.0	1.88	1.77	17.4	18.5
1994	5.5	5.7	1.89	1.76	20.2	16.2
1995	5.3	5.7	1.92	1.77	17.7	16.5
1996	5.1	5.4	1.93	1.81	17.6	14.6
1997	4.9	4.7	1.84	1.78	14.4	9.3
1998	4.0	3.9	1.93	1.83	9.2	6.2
Smelterville						
1988	11.5	10.5	1.87	1.70	71.0	53.9
1989	13.0	10.8	1.62	1.79	80.6	55.4
1990	9.0	10.2	1.56	2.27	30.8	50.7
1991	6.0	8.4	1.56	1.71	23.9	37.2
1992	7.4	7.5	1.62	1.80	31.5	30.9
1993	5.8	7.5	1.79	1.78	19.7	31.0
1994	5.3	6.5	1.67	1.78	20.8	22.3
1995	6.2	4.5	1.72	1.94	27.5	11.3
1996	5.8	2.9	1.60	2.03	11.8	3.9
1997	5.2	2.7	1.52	2.20	9.1	5.0
1998	5.8	3.1	1.54	1.75	14.0	1.8
Site Wide						
1988	8.5	10.2	1.74	1.94	46.2	50.9
1989	10.1	10.2	1.71	2.16	57.7	50.9
1990	7.9	6.6	1.62	1.99	37.3	27.3
1991	5.6	5.9	1.58	1.87	16.1	19.8
1992	6.6	5.8	1.64	1.87	27.2	19.3
1993	4.5	5.5	2.08	1.85	15.0	16.3
1994	5.2	5.1	1.83	1.81	17.1	13.2
1995	5.1	4.9	1.86	1.85	15.9	12.4
1996	4.8	4.4	1.85	1.90	12.6	10.0
1997	4.5	4.1	1.84	1.81	10.6	6.8
1998	4.1	3.7	1.86	1.83	7.8	5.0